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THE SURGERY OF THE EAR

THE TEMPORAL BONE

THE SURGERY OF THE EAR

BY

SAMUEL J. KOPETZKY, M. D.

Attending Physician, New York City Children's Hospitals and Schools; Attending Otologist to the New York Red Cross Hospital; Associate Surgeon and Instructor in Otology at the Eye, Ear, Nose and Throat Hospital; Otologist and Surgeon, New York Throat, Nose and Lung Hospital; Fellow of the American Laryngological, Rhinological and Otological Society; Fellow of the New York Academy of Medicine; American Medical Association, Otological Society of Germany, etc.

ILLUSTRATED WITH SIXTY-THREE HALF TONE AND LINE DRAWINGS, EIGHT CHARTS AND FIVE COLORED PLATES

SECOND EDITION

NEW YORK
REBMAN COMPANY
1165 BROADWAY

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REBMAN BUILDING
141-145 West 36th Street
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To

MR. MORITZ DOOB

This Volume is Dedicated as a Token of
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46475

PREFACE

THE present tendency toward specialism, if it continues, may result in a group of men who will devote themselves exclusively to the treatment of the surgical diseases of the ear. This tendency and the recent advances in otological surgery have created a need for a book which shall embody all the additions to our knowledge of the surgery of the ear.

With this aim in view the writer has attempted to correlate the extensive literature with personal experience and observations, and produce a volume adapted to the needs of the medical student, the practitioner and the specialist.

Acknowledgment is hereby made of the free use of the standard American and foreign textbooks, monographs and periodicals. The authorities consulted have been collected at the end of each chapter. These references are not given as the complete bibliography of the subject discussed, but are intended to indicate to those interested where additional matter may be found.

The procedures advocated have been fully tested. Each is preceded by a historical résumé and a sketch of the morbid process calling for operative intervention. Special stress has been laid on the indications for operation, the points of technique, and the after-treatment of the wound, including the general treatment of the patient, so as to make the book a practical guide in operating.

The illustrations are devised solely as explanatory pictures of the text.

The writer is indebted to *Mr. K. K. Bosse* for his care in making the drawings from the specimens and the fidelity with which he interpreted the author's idea in the schematic drawings. Thanks are due *Dr. R. Johnson Held* for many valuable suggestions; to *Dr. William W. Lesem* for reading manuscript, and to *Dr. L. D.*

Weiss for reading proof. It remains to express appreciation to *Dr. Wendell C. Phillips* for encouragement and support, and finally to *Mr. Francis J. Rebman* of the *Rebman Company* for valuable aid and timely suggestions which materially facilitated the publication of this book.

S. J. K.

New York City, U. S. A.

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THE SURGERY OF THE EAR

THE SURGERY OF THE EAR

CHAPTER I

OPERATIONS ON THE EXTERNAL AUDITORY CANAL

Surgical Anatomy—The Osseous Canal, Age Variations—Pathological Lesions of the Canal—Malformation, Congenital Atresia, Acquired Atresia—Intrameatal Operation for Atresia—Advantages and Disadvantages of the Intrameatal Route—Exostoses, Intrameatal Removal of Exostoses—Necrotic Areas in Canal—Inflammations of the External Auditory Canal, Furunculosis, Phlegmon, Abscess, New Growths, Foreign Bodies in Canal, Operative Removal of Foreign Bodies—The Auricular Operation—Indications—Operation—After Treatment—Value of the Operation.

Surgical Anatomy: The external auditory canal is the connecting link in the auricular apparatus between the external and the middle ear. It extends from the cavitas concha, or incisura intertragica of the concha to the outer (external) surface of the membrana tympani. Its length averages from 35 to 38 mm., and throughout its entire extent it is lined by cutis closely adherent to the underlying tissue.

Anatomically, it is divided into two parts, an external or cartilaginous portion, and an inner, deeper osseous portion. The juncture of these two portions is rather irregular, and dense fibrous tissue connects the two sections. The fibrous tissue is especially marked where the cartilaginous tissue is absent, namely, at the upper, and partially, on the posterior meatal walls.

The external auditory canal runs forward and inward in a generally oblique direction, gently bent upon itself, and presents a curve which is higher near the middle of its length than at either extremity.

The cartilaginous part occupies less than half of the length of the canal; it is formed by the prolongation inward of the cartilage of the concha and the tragus. It presents, at its upper and its posterior walls, deficiencies which are filled in by fibrous tissue, showing on its surface two or three fissures which run vertically. The presence of this membranous section makes this portion of the canal and the concha freely movable. Another factor tending toward the canal's mobility is the fibrous tissue connecting the cartilaginous portion to the bony portion of the canal. The mobility of the canal is of sufficient greatness to permit an almost entire straightening out of the canal, when the concha is drawn upward and backward.

The Osseous Canal: The osseous portion of the external auditory canal is formed in part from the squamosa and in part from the os tympanicum; these two bony parts are continuous behind. Where the os tympanicum abuts upon the mastoid process, there is a well-marked fissure known as the fissura tympano-mastoidea. The os tympanicum is separated in front from the temporal bone proper, by a fissure seen at the base of the zygomatic process, designated the fissura petrotympanica.

The rim of the bony opening—the porous acusticus externus, where it is a portion of the os tympanicum—is rough and broad, and presents an irregular triangular form (facies triangularis) to which the cartilaginous portion of the external auditory canal is attached.

The gap, above, left by the configuration of the os tympanicum, is filled in by a part of the squamosa of the temporal bone, known as the superficies meatus.

To aid our description, we divide the canal into an upper, a lower, an anterior and a posterior wall.

The upper and the posterior walls are shorter than the lower and the anterior walls, the oblique position of the drum being responsible for this difference in length.

The cartilaginous and the bony portions of the canal meet at an obtuse angle, causing a protuberance to project into the canal's lumen from the antero-inferior wall; this point is the narrowest section of the canal.

In form, the external auditory canal is that of an oval cylinder,

presenting a wider lumen at both conchal and tympanic extremities, than at the point of junction of the cartilaginous and osseous portions.

Bezold (1) publishes the following measurements of the canal's diameters at given cross sections:—

	Place of Measurement	Large Diameter	Small Diameter
1.	Beginning of cartilaginous canal	9.08 mm.	6.54 mm
2.	End " " "	7.79	5.99
3.	Beginning of osseous canal	8.67	6.07
4.	End " " "	8.13	4.60

A glance at Fig. 1 shows the shape of the lumen at the parts measured.

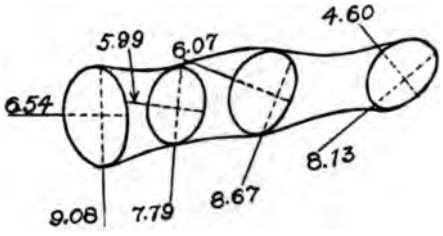

FIG. 1.—Showing the Form and Diameter of the External Auditory Canal at Various Depths, According to Bezold.

Age Variations: In young children the meatus is extremely short. The osseous section is more or less deficient, and in fœtal life it is entirely absent. At birth it presents as an incomplete bony ring. In the newborn the external auditory canal is really only a cleft. The osseous part is represented by the superficies meatus. This superficies meatus and the membrana tympani constitute the upper wall, and the concha is almost in intimate relationship with the superficies meatus. A true cartilaginous canal does not exist at this age.

As age advances, the membrana tympani becomes more vertical, the superficies meatus meanwhile bends upon itself to form an angle which, as adult life is reached, almost equals a right angle.

At birth, the upper and the lower canal walls are in contact; as the child grows these separate and widen the lumen of the

canal. The development of the os tympanicum from what at birth was only a bony ring, separates the membrana tympani from the cartilaginous canal.

The juncture of the osseous and the cartilaginous portions of the canal is of special surgical interest because the narrowness of the lumen causes foreign bodies located in the deeper parts of the canal to become impacted.

Pathological Lesions of the Canal Indicating Surgical Interference: Malformations: Various pathological conditions occur in the external auditory canal demanding surgical intervention. Some of the lesions are of congenital origin, others are the result of inflammatory processes, and some are due to accident or to trauma. The more important congenital lesions are malformations of the canal or its partial or complete absence.

Malformations are usually associated with malformations of the concha, and the attempt to correct the deformity of the concha is usually extended so as to render the canal patent.

Operative procedures, as a general rule, yield better results where the malformation is the result of accident or trauma rather than where it is of congenital origin.

Malformations vary in extent, kind and degree, from a simple closure of the canal lumen, to absence of the canal, or abnormalities such as duplication of the canal. *Macaulin* (2), *Guranowski* (3), and *Habermann*(4). In such cases, considerable ingenuity is required to meet the exigencies, and no hard and fast rule can be promulgated to meet all cases. Our efforts, necessarily, must be governed by the conditions present; the aim to establish a patent canal must be carried out with a care to obtain good cosmetic results. Fortunately this condition is rare.

No operation should be undertaken to correct maldevelopment of the canal, unless the middle and the internal ears are found to be intact.

Congenital Atresia: Of importance, in connection with maldevelopment of the canal, is congenital atresia. This may be bony, fibrous or membranous. *Knapp* (5), *Politzer* (6). The amount of atresia varies from partial closure to complete obliteration of the lumen of the canal. The graver forms of atresia

are usually associated with maldevelopment of the middle and the internal ears, and it is rare to find a well-developed concha present on the affected side, although occasionally it is found. *Link* (7), *Jacobson* (8), *Blau* (9), *L. Wolff* (10), *Breiger* (11), and others.

Schwartze (12) holds that invariably where grave one-sided atresia is present, a maldeveloped labyrinth also exists on the affected side, and substantiates his observations by the fact that a test fork placed on the middle of the top of the head is heard only in the normal ear.

Clinically, the auditory meatus may be present as a cup-like depression; or it may show a small orifice, terminating in a blind cul-de-sac, a few millimeters deep. In all these cases, it becomes essential to demonstrate the actual condition present. The character of the atresia, and the presence or absence of a functionating middle and internal ear must be determined. Acupuncture demonstrates the character of the atresia—whether it is fibrous, membranous, or whether underneath the membranous closure, bony atresia is present. When bony atresia is demonstrated, the question of surgical intervention rests on the proven presence or absence of a functionating auditory apparatus, the fork test for bone conduction deciding the question. It is presupposed that the patient is of sufficient age and intelligence to answer to this test, for unless the condition is bilateral, and because of fear of resulting deaf-mutism, it is better to wait with the surgical measures until the test can satisfactorily be made.

Operative procedures in congenital atresia of osseous character, where the functionating apparatus is involved, give poor results any way, and the suggestion of *Michael Jaeger* (13) that the mastoid antrum be opened in such cases in a manner similar to that employed in performing the simple mastoid operation, keeping the post-auricular wound permanently open to permit sound waves to reach the middle ear through the opening, may perhaps afford the surest relief to this condition.

In the other class of cases, where atresia is of fibrous or of membranous character, operative procedures either by the intrameatal or by the post-auricular route are indicated.

Surgical interference to be successful, therefore, is limited to the simplest forms of congenital atresia, namely, those where the absence of bony closure is demonstrable, and where the fork tests show the presence of a functionating auditory apparatus.

Acquired Atresia: Acquired atresia, the result of inflammatory deposits in the walls of the canal, is usually amenable to surgical treatment. Whether soft inflammatory, or osseous deposits, they act to impede hearing by lessening the diameter of the auditory canal; or where middle-ear suppuration is present, they are a hindrance to proper drainage and render the middle ear inaccessible to treatment. Inflammatory atresias result from granulation tissue fusing across the canal lumen, undergoing fibrous organization, and finally becoming enveloped in a covering of epidermis. No actual malformation is present.

Where active inflammation of the middle ear is present at the same time as the atresia, it is advisable to treat surgically the causative disease, at the time that the atresia is treated, for the continuance of the suppuration may not only cause a reappearance of the atresia, but the resulting wound is bathed in the purulent discharge from the middle ear, and this tends to further infect the canal walls.

Acquired atresias are open to surgical attack either by way of the intrameatal or the post-auricular route, the procedure selected depending upon the character and the location of the lesion presented.

In both congenital and acquired atresia, when the intrameatal route is chosen, the incision made depends upon the conditions present.

Intrameatal Operation for Atresia: A circular incision around the atresia, completely removing the obstruction, has been successfully employed.

The procedure of making two incisions placed at right angles to each other, creating four triangular flaps, excising one or the other of the membrane along the meatal wall to give a larger skin flap as in Fig. 2 *A*, has also given good results.

After removal of these flaps the underlying fibrous tissue is cut away and the flaps turned back against the meatal

FIG. 2.—Congenital Absence of Canal (Membraneous) with Lines Indicating Crossed Incision.

FIG. 3.—Same as Fig. 2, with Flaps Cut, Ready to be Turned Backward into Canal.

PLATE II

walls, the patency of the canal being meanwhile maintained by gauze tampons.

After a few days, usually after the fifth day, the flaps are found adherent, and the canal wall presents four granulating areas, to which applications of lactic acid are made to check exuberance of the granulations. Free use of antiseptic dusting powders, together with tamponage of the canal, gradually increasing the size of the tampons, leads to a successful result of the operation.

In cases requiring removal of bone, or in those in which the intrameatal attempts to relieve the atresia have failed, the post-auricular route should next be tried to relieve the condition.

Advantages and Disadvantages of the Intrameatal Route: The advantages of the intrameatal route are found to lie in the avoidance of a general anæsthetic, and in the fact that the procedure does not incapacitate the patient from pursuing his ordinary vocation.

Its disadvantages are shown in cases where large areas of obstructing tissue are uncovered, demanding removal; this cannot be accomplished as well through the meatus as through the post-auricular incision.

The post-auricular operation is described later.

Exostoses: Bony excrescences are usually found in the osseous sections of the external auditory canal. Partly the result of thickening or exuberation of the normal bone, they have been designated osteophytes by *Urbantschitsch* (14).

The usual location of an exostosis is on the upper wall of the canal, just in front of the drum. Occasionally, two excrescences are observed at the points where the anterior and the posterior walls merge into the upper canal wall. These are usually symmetrical, and are outgrowths from the annulus tympanicus at its anterior and posterior juncture with the squamosa. *Moos* (15) supposes them to be the result of pathological irritation during infancy, and they are thus considered a form of maldevelopment.

In general, the well-developed exostosis is found situated on the posterior wall. Exostoses of the cartilaginous portion of the canal are considered by *Green* (18) of congenital origin.

Exostosis is rarely seen in youth or in infancy, although *Field* (16) reports having observed this lesion at four years of age. In older individuals they are by no means rare; *Pierce* (17) reporting their occurrence 9 times in 300 cases. They vary in form; some being plainly circumscribed, having a broad flat base, while others are distinctly pedunculated in character.

Small exostoses do not require removal. Even larger excrescences which do not impede hearing require no attention; but when inflammatory conditions supervene, and their existence tend toward pus retention, or when they mechanically render the middle ear inaccessible to local treatment, they then require surgical removal.

If a middle ear suppuration is complicated by the presence of an exostosis of the canal, it is advisable to perform mastoidectomy and attempt the cure of the entire pathological condition, rather than to content one's self with the simple removal of the exostosis. The intrameatal operation to remove the exostosis under these conditions, renders the resulting wound liable to infection from the purulent discharge from the middle ear, and if the exostosis is large, demanding much chiseling to remove it, especially in nervous patients, a general anæsthetic will become necessary; therefore immediate mastoidectomy is strongly advocated.

In the absence of complicating middle ear suppurations, the removal of the exostosis may be accomplished either intrameatally or through a post-auricular incision.

Intrameatal Removal of Exostosis of the Canal: The patient is given a local anæsthetic, and the neighboring parts are rendered as surgically clean as possible.

The skin overlying the exostosis is incised and, if possible, retracted. It should be the surgeon's aim to save as much of the skin as possible, thereby avoiding an open raw surface. The skin is to be replaced after the removal of the exostosis.

After the skin has been pushed aside, a small chisel attached to a grip, bent so that its handle is out of the visual field, with the chisel's cutting edge under visual control, is now introduced, and placed against the exostosis. With a few short, light taps

of the mallet, the exostosis is planed off, and its protuberance leveled to that of the niveau of the canal wall. The retracted skin is now replaced and tamponed into position.

Where the exostosis is removed without regard to the preservation of the skin, the raw surface is dusted with an antiseptic powder, and the wound is otherwise treated as an open wound of the walls of the canal, special care being taken to prevent exuberant granulations from developing.

Wherever the intrameatal operation presents difficulties, or whenever the exostosis present is extensive, the post-auricular mode of operating offers the best results.

Necrotic Areas in the Canal: Ulcers of the canal may be limited to the soft tissue, or they may be superficial evidence of localized caries or necrosis of the underlying osseous parts. Furthermore, ulcers are either the result of inflammatory processes or they are the superficial degeneration of neoplasms.

Ulcers have been observed in connection with diphtheria, variola, and other general systemic disorders, and are not rare in tuberculosis (lupus), syphilis, or carcinoma.

Ulcer of the canal indicates intrameatal treatment. Its surface should be scraped, and then dusted with antiseptic powders, and the auditory canal lightly packed with gauze.

Caries or necrosis of the osseous portion of the canal is generally due to some inflammatory lesion. This condition is often associated with otitis externa. Furthermore, caries or necrosis of the canal, is often associated with a similar condition in the mastoid process. In this class of cases, the ulcer is usually located on the posterior superior meatal wall.

According to their size and location, necrotic areas are scraped either through the meatus, or after post-auricular incision into the canal. Intrameatal scraping is performed either with the spoon curette or *Richards'* curette. Thus the areas of necrotic tissue are removed; the surface is dusted and treated as an open wound. When the areas are large, or sequestra have formed, the post-auricular route gives better final results.

Inflammation of the External Auditory Canal: Inflammatory lesions of the external auditory canal are classified as circumscribed and diffuse, the most frequent circumscribed lesion

being a condition of furunculosis, and the diffuse condition being designated otitis externa.

By furunculosis of the external auditory canal is meant a characteristic circumscribed infection of the skin and subcutaneous tissue, usually located at some point in the cartilaginous portion of the canal, although occasionally the osseous section is the seat of lesion. Properly, a furuncle is a staphylococcus infection of a hair follicle; when infection takes place through a skin abrasion, an abscess or phlegmon develops.

Intrameatal treatment is indicated; the furunculous mass is incised, its contents evacuated, the small abscess cavity curetted and its walls touched with a solution of ortho-chlorophenol, followed by absolute alcohol. The little cavity is then packed or if too small, is dusted with an antiseptic powder. The canal is lightly packed with sterile gauze, which should be changed daily. In cases occurring as a complication of a pre-existing purulent otorrhœa, the latter condition must receive attention to prevent recurrence.

Phlegmons and abscesses are treated intrameatally, by evacuation of their contents, packing and dressings as described above. In cases where the inflammatory infiltrate is extensive, multiple incisions are indicated. In abscesses, the position of the incision varies with their location. When perichondritis is present, manifold incisions are indicated to deplete the parts and promote healing.

New Growths: New growths of the canal, if small, are removed with the snare, in a manner similar to that described for the removal of aural polypi. When the growth is of large size and the neighboring parts are involved, the post-auricular route should be selected to effect their removal. Considerable variations in the procedure are necessary depending on the size and the location of the growth.

Foreign Bodies in the External Auditory Canal: The entrance of foreign bodies into the external auditory canal, either by accident or by design, presents a condition often demanding the exercise of the greatest surgical skill to effect their removal. Although more frequent in childhood, foreign bodies are observed in the external auditory canal at all ages.

Foreign bodies may lodge either at the meatal orifice, at the junction of the cartilaginous and the osseous sections of the canal, or they may lodge so deep in the meatus as to lacerate the drum, and occasionally force an entrance into the middle ear.

The animal, the vegetable and the mineral kingdoms are represented by the various objects found in the canal. Insects, maggots, plants, beans, fruit seeds, stones, beads, and glass particles, are samples of a large collection taken from the auditory canal.

The presence of foreign bodies is demonstrable upon inspection, and by the cautious use of the probe, together with a study of the history of the given case. Deaths have resulted from unskillful attempts at removal, cases being reported by *Weinlechner* (19), *Wendt* (20), *Szokalski* (21), *Fränkel* (22), and others.

Operative Removal of Foreign Bodies: The simplest and most efficacious method to remove small foreign bodies consists in the forcible syringing of the external auditory canal with lukewarm water, as originally suggested by *Celsus* (23).

Where the foreign body is a living insect, it is well to first kill the insect. This is done by introducing a few drops of chloroform into the meatus upon a cotton plug.

In cases where the foreign body is small, and of such shape that syringing fails to dislodge it (glass beads, etc.), removal is indicated by the *agglutination method.* This consists in introducing a cotton-capped applicator, wet with a sticky substance, preferably collodion, and bringing it into contact with the foreign body. After a few moments, the body is found to adhere to the cotton-capped applicator, and can then be successfully removed.

Where inflammatory swelling, due to irritation, is present, it is found advisable to first treat the inflammatory condition and only after the absorption of the infiltrate, to attempt the removal of the irritating body. Granulations or adhesive bands, which develop about a foreign body which has been *in situ* for a considerable time, demand removal before the foreign body can be extracted.

In cases where the foreign body is large, and is not removable by syringe or the agglutination method, instrumental extrac-

tion is indicated through the meatus. Small, delicate hook-shaped instruments are carefully introduced behind the object, care being exercised not to injure the membrana tympani, secure a hold on the foreign body, and cautiously extract it. Vegetable products are removed piecemeal, the final detritus, reduced in size, being washed away by a water douche. When operating through the meatus, the canal walls must not be unnecessarily injured, as infections may result with unpleasant sequelæ.

Failure to extract the foreign body through the meatus is followed by removal of the object through the post-auricular route.

The after-treatment of intrameatal removal consists in dusting all excoriated areas, and keeping them surgically clean, watching the granulations to check their exuberancy, until the epidermis has covered the raw areas.

The Post-auricular Operation: Historical: Incision into the posterior canal wall after post-auricular incision and retraction of the soft parts, for the removal of foreign bodies, was first practiced by *Paul of Aegina* (24), although it is surmised from the writings of *Fabricius ab Aquapendente*, *Leschevin* and *Itard*, that the operation was then only suggested upon theoretical grounds, and had not been actually performed upon the living subject. Of the earlier writers, *Duverney*, *v. Tröltsch*, *Rau* and *Lucae* considered the post-auricular operation as quite valueless. On the other hand, *Schwartze* favored its employment to remove deeply situated foreign bodies, and his assistant, *D. Eysell*, 1870, reported good results. Since then, *Israel*, *Langenbeck* and others have used post-auricular incision not only to remove foreign bodies, but as a means to successfully attack other pathological lesions in the external auditory canal (25).

Indications: The post-auricular operation is indicated in all lesions of the external auditory canal where free access is desired to the deeper parts of the canal. In congenital or acquired atresias, where elaborate flaps must be cut; in extensive exostoses, where large areas of osseous tissue require removal; in foreign bodies solidly wedged in the depth of the auditory canal or in the tympanic cavity; in the presence of new growths of

large size or extensive area involvement; in extensive necrotic areas or caries whether associated or not with sequestra formations; in all these classes of cases, the post-auricular method of approaching the lesion is indicated, and gives the best surgical after results.

Whatever the special indication may be, calling for this procedure, the main steps of the operation are the same. The procedure is varied to meet the given requirements after the external auditory canal has been opened to expose its interior.

The Operation : The patient is prepared for general anæsthesia, and local parts cleansed and dressed, as described in preparing a patient for mastoidectomy.

The operation begins by making an incision, one-quarter inch behind the auricular attachment, paralleling the line of attachment from its upper to its lower limit. The incision should be made with a sharp knife, and with one sweep, carried through all soft tissue down to the underlying bone. Bleeding points are speedily secured, and while hemorrhage is usually insignificant, occasionally free bleeding results from the severing of the post-auricular artery.

The concha is now pulled forward and turned upon itself, and the periosteum and soft parts are pushed as far forward as possible, exposing to view the posterior wall of the membranous canal. An elevator, or other blunt instrument, is gently inserted along the posterior canal wall, between the membranous wall and the bony parts, separating the membranous section from the bone.

Often during this maneuver, the canal wall tears at the juncture of its soft with its osseous section, and the interior of the external auditory canal is in view. In cases where this does not occur, an incision is made sufficiently large to accomplish the end in view (removal of foreign body, extraction of exostosis, etc.).

After the hemorrhage has been controlled, the concha and its attached canal portion are pulled forward, and held there during the subsequent procedures.

If the operation has been undertaken to relieve atresia, suitable flaps are now cut and the obstructing tissue removed.

Where exostoses demand attention, their removal is accomplished by the chisel, introduced through the opening in the canal. The curettement of necrotic areas or the extraction of new growths is also accomplished through the incision in the canal wall.

The object of the operation attained, the soft parts of the canal are carefully replaced and tamponed into position. The post-auricular skin wound is sutured and an external dressing applied.

After-treatment: The canal wall usually requires no suture, the tampon being sufficient to keep it in position, and prevent occlusion of the lumen of the canal. After five days, the dressings are removed, the stitches are taken out, and a light collodion dressing applied to the line of incision behind the concha. A few days more suffice to complete healing. Many surgeons do not incise the canal wall, but content themselves with tearing through it. The results are equally good in either case.

Value of the Operation: This simple procedure possesses great value, not only because it affords a clear unobstructed view of the deepest parts of the auditory canal, but also because it provides a positive means for relieving atresia by rendering it possible to make suitable flaps. Furthermore, it permits the removal of foreign bodies without inflicting unnecessary trauma to the membrana tympani, and it offers the best means to eviscerate necrotic areas, sequestra formations and new growths.

It possesses few dangers under ordinary aseptic precautions, although the potential infection of the cartilaginous canal is to be borne in mind. In cases complicated by middle-ear suppuration, it is well to have it understood beforehand that, mastoidectomy may be undertaken at once, if the findings warrant it, to avoid further delay, as the post-auricular incision is similar to that made for the operation on the mastoid. In such cases, mastoidectomy may be proceeded with, should the necrotic areas be extensive or an obstructing osseous atresia be uncovered. Where primary union results, the operation leaves only a slight scar, and even this is hid by the concha.

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CHAPTER II

PARACENTESIS

Historical—Classification of Middle Ear Diseases—Indications for Paracentesis Schwartze—Indications in the Light of Our Present Knowledge—Surgical Anatomy of the Membrana Tympani—Preparation of the Patient—Anæsthetic—Incision—Dangers of Paracentesis—After-treatment—After Effects—Treatment of Slow Healing Perforations—Value of the Operation—Immediate Effects to be Expected.

Historical: Relative to the simplicity and the ease of its execution, there probably is no procedure of an operative nature in otology, which gives such brilliant results as are obtained from paracentesis, when intelligently used.

At first, it was advocated and used by a Parisian charlatan named Eli, who flourished in the latter part of the eighteenth century. It is generally ascribed as having had its first legitimate employment at the hands of *Himly* and *Cooper*, during the beginning of the nineteenth century. As a matter of fact *Cheselden* (1), 1720, and *Busson* (2), 1748, had already advocated the measure, and *Wilde* reports that *Dr. Peter Degravers* (3), an Edinburgh physician, wrote of the procedure and its indications in 1788.

Himly (4), of Göttingen, demonstrated paracentesis on the cadaver in 1799, and performed the first operation upon the living subject about 1806. Meanwhile, *Astley Cooper* (5), in 1801, published his first successful attempt at the operation. These observers used paracentesis as a means to improve hearing in cases of stricture of the Eustachian tube.

Their results brought about a rather promiscuous employment of this procedure in all kinds of cases in which deafness was a marked symptom. This abuse, against which *Himly* protested, gradually caused the operation to be abandoned.

Individually reported cases, wherein success was reported in improving hearing, continued to be made. Thus *Kern* and *Rust*, in Germany, and *Saunders* in England, and *Itard* in France, are cited by *Schwartze* (6), as having successfully used the procedure. We are indebted to *Schwartze* (7) for placing paracentesis upon a sound scientific basis, and giving this little operation its proper place in otological surgery.

Before attempting the discussion of the indications for paracentesis, and in order that the conditions calling for its employment may be better understood, let us briefly sketch the classification of middle ear diseases.

Classification of Middle Ear Diseases: We classify the middle ear diseases according to their clinical aspect, which in accordance with the views of *Politzer*, *Walb*, *Jacobson*, *Heine* and others (8), divides them into two general classes. On the one hand middle ear catarrhs, and on the other middle ear inflammations. The former caused by mechanical closure of the Eustachian tube, and the latter produced by the invasion of pathogenic micro-organisms.

The otoscopic picture in middle ear catarrhs is the result of the absorption of the air from the tympanic cavity, due to the tubal closure. The otoscopic picture presents a reddish, retracted drum, upon which a pathological fold is often evident, running from a point behind and below the processus brevis toward the posterior drum margin; this pathological fold is designated the "posterior fold." Shrapnell's membrane is usually drawn inward, and presents a pathological light reflex at the point of its greatest concavity. The malleus handle inclines toward the promontory, and consequently appears foreshortened; its processus brevis is usually sharply outlined in "bas-relief," and from it, when the drum retraction is markedly distinct, a small pathological fold is often observed running forward toward the drum margin.

In contradistinction with chronic cases, in acute middle ear catarrhs, instead of presenting a pearl-gray color, the drum shows red, with blood-vessels injected about the malleus handle; occasionally these injected blood-vessels are absent.

The red tinge of the drum is due to the general hyperæmia of

the lining mucous membrane of the tympanic cavity, which includes the mucous layer of the drum itself in its hyperæmic process. The hyperæmia is the result of air rarefication in the tympanic cavity. In its other layers the drum remains unchanged. It presents no loss in reflective power or translucency.

The end result of the air absorption from the middle ear is presented in the mechanical formation of a *transudate*, which, depending on its amount, will be demonstrable on the drum by a line of demarcation, denoting its upper level. No line of demarcation between fluid level and the rest of the cavity is seen when the entire tympanic cavity is filled with transudate. The production of the transudate is checked as soon as the tympanic cavity becomes filled, or when compensatory pressure has become established, and this is the reason that no bulging of the drum is observed in middle ear catarrh.

The findings of the otoscopic picture are substantiated in the establishment of the diagnosis, by comparison with the opposite side, provided, of course, that the opposite ear is healthy, and by the interpretation of the auscultation sounds during catheterization of the affected ear. A comparison of the drum picture after catheterization, with the findings before the employment of the Eustachian catheter adds valuable data toward diagnosis. The level of the transudate will be found to have changed and the presence of air bubbles in the fluid will be evident.

By middle ear inflammation we mean an inflammatory involvement of the tympanic cavity due to the invasion of pathogenic micro-organisms. Middle ear inflammations usually are an extension by contiguity of an inflammatory process from the pharynx, which successively involves the pharyngeal mucosa, the mucous lining of the Eustachian tube, and finally the mucous lining of the tympanic cavity.

The otoscopic picture in middle ear inflammations differs radically from that observed in the middle ear catarrhs. Here we find that the drum presents a dull, flat, glossy appearance, its transparency is lost, and there is no evidence of retraction in well-marked cases. The blood-vessels of the malleus handle are usually strongly injected. The processus brevis not only does

not stand out sharply, but on the contrary its outlines gradually become effaced.

As *Heine* points out, there exists a stage in the inflammatory process, which strongly simulates acute middle ear catarrh, and the differentiation between the two diseases at this stage presents considerable difficulty. Furthermore, border-line cases are occasionally met with, which are hard to classify in one or the other category; and finally a catarrhal process, upon the advent of bacterial infection, may merge into an acute inflammatory lesion.

As the inflammatory process develops, an *exudate* is thrown out into the tympanum, the mucous membrane lining the middle ear meanwhile swelling. The inflammatory infiltrate spreads to the fibrous and elastic layers of the drum, resulting in an alteration of the otoscopic picture. The malleus handle is now obliterated, and as the swelling of the drum continues, the processus brevis finally disappears from view, or remains as a small white spot on the dark red background of the swollen drum.

The production of the inflammatory exudate continues, and as its amount increases within the tympanic cavity, it exercises a continual pressure on all sides, which is relieved only partially by the outward bulging of the drum; this tension causes the intense pain experienced by the patient.

The process either continues until spontaneous perforation of the drum takes place, or it becomes arrested in its development, and the inflammatory exudate is absorbed; when the condition has fully retrograded, and the lining mucous membrane of the tympanic cavity again becomes normal, recovery is complete.

In children, either because of the greater resistance offered by the membrana tympani, or, what I believe more probable, because the Eustachian tube at that age is shorter, straighter and of larger lumen than at any subsequent time, the inflammatory exudate does not spontaneously perforate the drum as readily as in adult cases, but the excess of exudate discharges itself through the Eustachian tube into the pharynx. I have observed in cases among children, where the patient gave unmistakable signs of suppurative middle ear disease, and where in the ordinary run of such cases a perforation of the drum would

have been formed, that the drum was found intact, and that only upon a careful examination of the posterior and lateral pharyngeal walls was it evident that the purulent discharge was being thrown out from the pharyngeal orifice of the Eustachian tube. Occasionally, I have seen the discharge from the pharyngeal orifice of the tube appear externally as a purulent nasal discharge; this occurred in very young children.

It is worthy of note that *Zaufal* and *Piffl* (14) recently called attention to the course pursued by the middle ear inflammations among children. These observers remarked typical cycles manifesting themselves in genuine middle ear inflammations. These cycles resemble the cycle of the course of pneumonia. Starting with a chill, the disease is accompanied with a high fever and excessive pain and the characteristic otoscopic picture; this lasts for from seven to eight days when a rapid turn toward recovery supervenes, no perforation of the drum having taken place.

In middle ear inflammations, diagnosis is made on the given history, the clinical symptomatology, and the otoscopic picture. No resort to the use of the catheter is advised; on the contrary it is regarded rather as a dangerous procedure. The middle ear is full of pus, usually to the limit of its capacity, often under considerable pressure, and the forcible introduction of air through the Eustachian catheter is likely to force the purulent contents of the tympanic cavity, along the line of least resistance, and thus infect the aditus ad antrum, and then the mastoid cells previously uninvolved, if indeed it does not succeed in producing graver sequelæ.

Having now briefly sketched the types of middle ear affection, we will discuss the indications for paracentesis.

Indications for Paracentesis (Schwartze): *Schwartze*, to whom we have referred as having given paracentesis its scientific basis, considers the procedure indicated:—

1. In cases of acute and chronic catarrh with so excessive an amount of transudate in the middle ear that the drum bulges, or in cases wherein during inflation no auscultation sounds are audible; and also in cases where conservative treatment—especially catheterization is without beneficial effect:

2. In cases of otitis media purulenta acuta which fail spontaneously to perforate the drum:

3. In cases of otitis media purulenta chronica with insufficient perforation, or where the perforation is situated high upon the drum, or where there is exhibited evidence of pus retention:

4. In cases of myringitis, presenting a greatly swollen drum and causing excessive pain:

5. In cases where it is determined to incise the membrana tympani to establish positively the presence or absence of exudate within the tympanic cavity:

6. In cases where it is desirable to produce an improvement in hearing by severing intratympanic adhesions.

Indications in the Light of Our Present Knowledge: In the light of a more thorough knowledge not only of the symptomatology but also of the pathology of middle ear disease, *Schwartze's* indications for paracentesis have undergone considerable modification, although the main points laid down by him are as true to-day as they were at the time they were first advocated.

We no longer perform paracentesis in the catarrhal conditions. Realizing that the drum is of relatively small importance to the act of hearing, we do not incise it in an attempt to better this faculty, and while it is true that an incision in the inflamed and swollen drum, by depletion and relief of tension often aids toward recovery, we do not usually resort to paracentesis for myringitis, as such cases usually resolve without resort to this procedure.

Generally speaking, paracentesis is indicated in acute inflammations of the tympanic cavity, where the drum presents either a circumscribed or a diffuse bulging. Purulency of the exudate within the tympanic cavity is often demonstrable through the drum by the slightly yellowish tinge which it imparts to the red drum; concomitantly, the clinical picture reveals a febrile curve, and intense pain in the affected ear.

Drum bulging, fever and localized pain are indications subject, however, to individual variations. While children almost invariably present high fever as a constant sign, in adults, the fever, if present, consists in only a slight rise in temperature. In infants, I have observed a loss of weight, and the advent of

diarrhœa where no error in diet had taken place; this refers to artificially fed infants. The loss of weight and diarrhœa are also present in breast-fed infants.

Neither must a bulging drum be considered a sign invariably indicating the presence of a purulent exudate; cases have been observed where bulging has appeared, due to an excessive swelling and infiltration of the lining mucous membrane. There are cases observed where the drum presents a diffuse swelling, is of bright red color, and yet so coated with loosened epidermis scales that the condition of the middle ear can not be determined. Among children, especially among infants, it is often an impossible task to view the drum at all, as the external auditory canal is narrowed and partially filled with a mixture of epidermis and cerumen. Furthermore, among the aged, whose drums have become thickened, it is a difficult task to establish the fact that bulging of the membrana tympani exists.

These obscure cases are usually the most dangerous, as delay in resorting to paracentesis may aid toward the extension of the diseased area, not only to the mastoid region but also to the internal ear, if not to the cranium.

There are authorities who recommend the employment of the Eustachian catheter as an aid in clearing up the diagnosis in these cases, and to establish the presence or absence of pus in the middle ear; for the reasons cited above, and in view of the published reports of mastoid cases which have resulted from this maneuver, we agree with *Heine* that the procedure is a dangerous one and not to be employed in these cases. Nor should the obscure cases be operated upon promiscuously. Since *Politzer* demonstrated that bacterial invasion of the tympanic cavity will take place more readily through the Eustachian tube from the pharynx when the drum is perforated than when it is intact, we hold it well to pause before proceeding to paracentesis unless the indications are clearly met. Cases have been under observation wherein the amount of exudate has been small, and the extent of the inflammatory process limited; such cases have recovered without resort to paracentesis. However, in doubtful cases, it is better to err on the side of safety, and to incise the drum early, since the chances of infecting a

sterile tympanic cavity are less dangerous to the patient, where proper precautions against infection are taken by the surgeon, than the grave sequelæ which an undetected and an unrelieved purulency of the middle ear threatens.

Useful guides are presented in the condition of the mastoid and the general symptoms of the patient. In doubtful cases, paracentesis is indicated where the pain is severe, and where the patient is forced to pass sleepless nights, presenting a mastoid which is tender upon pressure and which gives evidence of some infiltration of the soft tissues over the mastoid: in infants, when the child rolls its head on the pillow, sucks with difficulty, or interrupted by pain cries, but swallows readily when given nourishment by the spoonful, and where handling of the ear evokes pain cries, under these conditions paracentesis is indicated.

With absence of pain but presence of tenderness over the mastoid tip, and with absence of all evidence of pain over the mastoid antrum, expectant treatment may cautiously be tried.

In all cases where symptoms of pus retention are presented, per example—an exudate coming away under pressure—with pulsations, from a spontaneous perforation, and in all cases evidencing meningeal irritation, there the spontaneous perforation must be enlarged, or if in the latter class of cases, no perforation is presented, then paracentesis is urgently called for.

Some observers, *Katz*, *Zaufal*, and others, defer the performance of paracentesis until later in the course of the disease, *Zaufal* being governed by his known views on the pathological cycle in middle ear diseases already referred to. We hold with the majority of otologists against this stand, and believe that paracentesis is indicated and should be performed as soon as a fairly positive diagnosis of tympanic purulency is established.

Before describing the procedure itself, and because its intelligent performance demands it, we present a brief outline of the surgical anatomy of the membrana tympani.

Surgical Anatomy of the Membrana Tympani: The membrana tympani, or drum, is a thin, transparent, delicate membrane, averaging about 0.1 mm. in thickness. It closes the bony auditory meatus at its medial extremity, and forms the

outer (lateral) wall of the tympanic cavity. At its periphery, it is fastened in the sulcus tympanicus, its bony framework being completed above by the squamous plate of the temporal bone.

The mesial (inner) end of the external auditory meatus does not present a perpendicular plane to the long axis of the meatus, but is placed at an inclined plane which passes obliquely toward the long axis. Measured from the concha the lower margin of the drum lies at about a depth of 6 mm. deeper than the upper margin. The tympanic membrane thus forms with the horizontal plane an angle of from 44° to 55° opening externally (9). The drum at the same time forms another angle than that just described; it lies on a plane of about 50° incline toward the sagittal or median plane of the head. This angle opens posteriorly and is measured in the horizontal plane.

A slight modification of these angles is produced by the gradual descent of the upper and lower meatal walls to meet the drum postero-superiorly, and antero-inferiorly. The roof and the floor of the external auditory meatus descends obliquely toward the membrana tympani, the posterior-superior wall merging so gradually into the membrana tympani that an actual angle cannot be said to be formed; *v. Troltsch* estimates this potential angle at about 140°.

From the practical surgical standpoint, it is to be noted that in pathological processes in this region, the boundary between the auditory meatal canal and the membrana tympani often becomes obliterated, and when operating upon the membrana tympani, the surgeon must bear in mind that the postero-superior portion of the drum lies much closer to the eye (as viewed from the meatal orifice) than does the antero-inferior portion.

In form, the membrana tympani is irregularly oval, its superior part—the margo tympanicus—being somewhat deeply curved. Another, but smaller, indentation is present, situated above the processus brevis of the malleus; this is formed by the squamosa of the temporal bone, and is designated the "Incisura Rivini." It varies as to size and form, averaging, however, about 2 mm.

The handle of the malleus passes as a gray streak from a position near the upper circumference of the membrana tympani to a little beyond its center, the processus brevis projecting near its upper end as a small white protuberance. See Fig. 4, Plate III.

The neck of the malleus passes upwards and becomes invisible from the meatal orifice, its inclination being away from the internal surface of the drum. At its visible portion, the malleus handle inclines inward at about an angle of 30° in such a way that owing to its attachment to the internal surface of the drum, it draws the membrana tympani inward towards the tympanic cavity. This gives the drum somewhat the appearance of a flat cone; the malleus tip—the umbo—forming the apex and the margin of the drum the base of the cone.

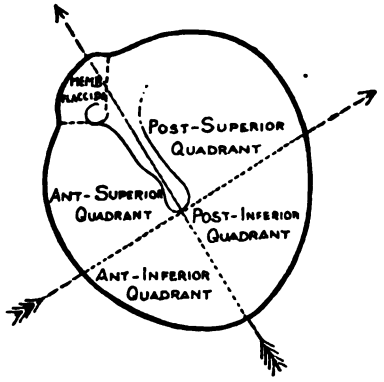

FIG. 5.—The Quadrants of the Membrana Tympani.

For practical purposes, anatomists, physiologists, and otologists have divided the membrana tympani into two parts, the pars tensa and the pars flaccida or Shrapnell's membrane. The pars flaccida, or Shrapnell's membrane, corresponds to a small concentric-shaped field situated between the processus brevis and the Incisura Rivini; the pars tensa comprises the entire remainder of the drum surface. This division is justified upon clinical, physiological, and anatomical grounds. (Fig. 5.)

From time to time there have been proposed other divisions of the membrana tympani, but in addition to the division cited above, the plan which divides the drum into four radiating fields or quadrants is most practical.

Imagine a line drawn as the prolongation of the malleus handle, extend it to the drum of the periphery and we have divided the membrana tympani into an anterior and a posterior half. Imagine a second line drawn across the drum surface so as to bisect the first line perpendicularly at the level of the umbo

and the membrana tympani is divided into four fields, or into an anterior superior, an anterior inferior, a posterior superior and a posterior inferior quadrant. The quadrants thus obtained are not of equal size, because the umbo lying somewhat in front and below the center of the membrana tympani, makes the anterior portion of the drum naturally smaller than the posterior, and the upper portion larger than the lower; the smallest quadrant is the anterior inferior and the largest the posterior-superior.

This division of the drum into four quadrants has not been made arbitrarily, as the quadrants have clinical significance in so far as different prognostic data obtain from perforations located in these different quadrants. For example, other things being equal—the prognosis is best when a perforation is located in the postero-inferior quadrant, and the prognosis becomes progressively worse when the perforations are located in the antero-inferior, the posterior superior and the antero-superior quadrants respectively, the outlook from the standpoint of prognosis being worse in the order above enumerated. Finally, it is to be noted that Shrapnell's membrane—pars flaccida—slants at a somewhat different angle than the rest of the drum, and consequently appears differentiated from the remainder of the drum. Its lower outlines are formed by one or two flat folds, designated the anterior and the posterior boundary columns.

Preparation of the Patient: Before paracentesis is undertaken, the external auditory canal should be thoroughly cleansed. This cleansing must be performed gently because of the sensitive nature of the inflamed parts. The patients have usually been suffering from severe pain for some time and all unnecessary manipulation is naturally resented.

We have found it effective to fill the canal with a solution of Pyrozone; the patient meanwhile holds his head toward the opposite side, and permits the cleansing solution to remain in the external auditory meatus for about two minutes. Carefully removing this, we follow it by an alcoholic solution of bichloride of mercury. Careful drying of the canal follows, and we are ready for the operation. The concha and the neighboring skin have in the meanwhile been carefully cleansed with green soap, alcohol, and bichloride of mercury.

Schwartze recommends not only an attempt at thorough disinfection of the external auditory canal and its surroundings, but also a careful cleansing of the naso-pharyngeal spaces. That these measures are important cannot be denied, and while we do not believe that it is possible to render the nasopharynx and the external auditory canal sterile, still these precautionary measures should be undertaken as a routine measure, our aim being to get as near asepsis as conditions permit.

The Anæsthetic: Combinations of various drugs with cocaine have from time to time been advocated as a local anæsthetic, but personal experience has found them usually ineffectual.

We do not use the combination of phenol, menthol, and cocaine, extensively employed by many aural surgeons, because the phenol so acts upon the delicate tissue of the drum, that it destroys the clinical picture, and after paracentesis is performed, on the succeeding days after the operation, we find ourselves confronted with a discoloration of both the membrana tympani and the canal due to the caustic action of this drug. Our judgment of the progress of the pathological process is thus interfered with, and in some cases I have observed a myringitis produced from the action of the phenol, where none existed previously. Finally, in a certain number of cases, the combination of phenol, menthol, and cocaine afforded no relief to the pain from the incision. Its employment, like that of the alcohol, the cocaine, and the aniline oil of European surgeons, may perhaps find its best explanation in the "suggestive" effect it has upon the patient.

Local anæsthesia administered as suggested for the performance of ossiculectomy (Chapter V), may find advantageous employment before paracentesis. Here a solution of cocaine (1 per cent.) in adrenaline (1:1000) is injected into the external auditory canal; this usually effectively anæsthetizes the membrana tympani.

When we impress upon patients the fact that the actual pain from the incised wound is slight indeed when compared to the suffering they have already undergone, or are undergoing, we find that usually it is possible to perform this procedure without any local anæsthetic at all. In nervous patients, in women, and

especially in children, the best anæsthetic for paracentesis is nitrous oxide gas, although ethyl bromide has also found favor.

Where local anæsthetics are employed, or where all anæsthetics are dispensed with, the upright posture should be maintained by the patient, with the head fixed by an assistant. General anæsthesia presupposes the reclining or recumbent posture.

The Instruments: The paracentesis knife should be of razor sharpness, terminating at a fine point. It may be either lance-shaped or slightly curved like a small bistoury. Personally we have employed the lance-shaped paracentesis knife as designed by *Lucae*, with the bayonet handle. The advantage of this handle lies in the fact that it permits the operating hand full play, without obstructing the visual field of the operation, and the eye is enabled to control the tip of the knife during the entire maneuver.

The Incision: In cases which have not perforated, and which present a bulging drum, the site of election for the incision is the posterior inferior quadrant, carrying the cut as near the peripheral margin of the drum as it can conveniently be placed. This place is selected for the incision because it affords the best method of drainage for the tympanic cavity, opening it at its lowest accessible part. (See Fig. 6. Plate III.).

In making the incision the anatomical position of the drum should be borne in mind. The tip of the knife is introduced at a point close to the annulus tympanicus, and is carried downward from this point toward the front below, the blade sinking deeper as we descend on the drum so that the drum is not missed in its lower parts, a technical error likely to happen because of the angle of inclination of the drum.

In cases where the drum bulges in any of the other quadrants, the incision is then placed, not at the point of selection, but at the spot which presents the most marked bulging. Should the bulging be most marked at Shrapnell's membrane, either anteriorly or posteriorly, then the paracentesis is so placed in the region affected, that the incision is made parallel to the long axis of the bulging part.

The incision made at the point of selection is usually a curved one, it severs the radiating fibers of the drum, thus causing the

FIG. 4.—The Normal Drum.

FIG. 8.—Aural Polyp, Protruding Through Drum at Shrapnell's Membrane.

FIG. 6.—The Incision of the Membrana Tympani. (The Site of Election.)

FIG. 9.—Polypoid Granulations.

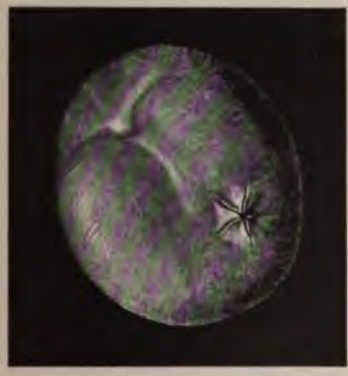

FIG. 7.—An Irregular Shaped Spontaneous Perforation.

FIG. 13.—The Incisions Made in Membrana Tympani, in Front and Behind the Carious Hammer Handle.

PLATE III

wound made in the drum to gap. This is accounted for by a loss of elasticity in the fibers composing the drum membrane, and is based on an observation of *Helmholtz* (10) that elasticity is lost when one set of drum fibers is severed. The original observation was made while incising the circular fibers, but *Heine* after many years' observation, finds that gaping likewise results when the radiating fibers are cut, as happens when the incision is made as described above.

Gruber (11) begins the incision 1 to 1½ mm. from the drum margin, and curves the incision so as to parallel the canal wall. Necessarily, the incision must depend upon the circumstances presented by the case; thus in certain cases the V-shaped incision advocated by *Haug* (12) is employed. It has been found to be especially useful in cases where spontaneous perforation has left an irregular opening which inadequately provides proper drainage. Occasionally the spontaneous perforation will be found so irregular that to secure adequate drainage, the entire mass will require removal. In these cases, the protruding mass springs forward into the auditory canal, and from its tip, through the irregular opening, the purulent exudate is observed coming away under considerable pressure. (Fig. 7. Plate III.)

The removal of such protrusions of the membrana tympani is best accomplished by biting off the mass with a *Hartman's* forceps. The perforations in a suppurating middle ear, which manifest a tendency to close, must be reopened, and it occasionally happens that repeated paracentesis is necessary.

In performing paracentesis, the knife should not be brought into contact with the external auditory canal wall, either before or after the knife has cut the drum. It is a technical error to bring the edge of the knife which has just been plunged into a suppurating cavity (tympanic cavity) against the canal wall and perhaps cause excoriation of the skin lining the canal. I have seen a diffuse external otitis supervene from a local infection thus started. In making the paracentesis incision, care should be exercised that the knife is not introduced so deeply into the tympanic cavity that its point impinges on the internal (median) tympanic wall. This technical error results in an increase in the amount of pain not only at the time of the

procedure, but the pain lasts very much longer after the operation.

Dangers of Paracentesis: The performance of paracentesis presents some dangers, which, however, with care, are generally avoidable.

The incubo-stapedius articulation may receive injury from the edge of the knife when the incision is made in the posterior superior quadrant, because of local bulging in this region. The little joint may be dislocated, the arms of the stapes fractured, or the entire bone may be torn from its articulation at the oval window. I saw a case of the last-named accident four years ago when the paracentesis was followed in about a week by a labyrinthitis and a fatal meningitis; the paracentesis had been performed by the family physician before the case was brought to the hospital.

When making the incision in the posterior-superior quadrant, the knife should be partially withdrawn as soon as it is felt to impinge against a hard resisting substance. As we withdraw the knife, we feel it slip over the obstacle, and then we continue our incision to the desired extent. The knife must always be held very lightly; a knife properly constructed, if sufficiently sharp, will make the incision by its weight alone, if held lightly. Employment of force is to be deprecated. The chorda tympani is occasionally severed by the paracentesis incision, and derangements of the sense of taste on the affected side follows. This accident, while annoying, is not of very serious import.

The possibility of injury to the jugular bulb is a danger to be remembered when operating upon children. In these young patients, it is found that the floor of the tympanic cavity very often arches, to some extent into the tympanic cavity. The floor of the cavity, covering the jugular bulb, is always thin, and often shows dehiscences, and the knife may either easily break the bony partition, or penetrate it, thereby injuring the jugular bulb. *Körner* (14) cites five cases where such an accident happened.

Among the same class of patients, namely children, there exists a possibility of injuring the carotid artery. This danger is present when the local manifestations indicate that the para-

centesis should be made in the anterior inferior quadrant. This quadrant lies deepest from the surgeon's eye, and to reach it the knife must be pushed inward some millimeters deeper than is necessary to place the incision in the posterior quadrants. The danger of injury to the carotid in these cases must, therefore, be regarded as a potential one. Fortunately, the occasion is rare which demands the placing of the incision in the anterior inferior quadrant.

After-treatment: Following the performance of paracentesis, the purulent exudate and the resulting hemorrhage should be permitted to flow uninterruptedly for some minutes, after which the external auditory canal should be thoroughly cleansed. The paracentesis wound requires frequent inspection to insure its patency, otherwise no local treatment is demanded.

Further measures in the treatment of the middle ear inflammation are not given in this work, as the therapeutic measures indicated will depend upon the pathological conditions present, and are not properly treated in a book on the surgery of the ear.

Suffice it to indicate such measures, as rest in bed, repeated douchings of the affected ear with hot solutions of bichloride of mercury (1:2000). Some authorities, on the other hand, place gauze drains in the external auditory canal. Generally, bed rest, abstinence from business, avoidance of tobacco and alcohol, and a light diet are indicated.

After Effects: In the ordinary course of events, the wound in the drum heals without incident at the subsidence of the middle ear inflammation. The perforation persists from a few days to some weeks. As we have already said, the tendency to closure of the paracentesis wound is often so marked that the operation must be repeated. The drum wound after healing usually leaves no scar to mark its site, if the cutaneous layer of the drum has escaped inflammatory involvement. Scars on the drum are generally the result of spontaneous perforations, or where the inflammatory process involved all the layers composing the tympanic membrane.

It is to be noted in passing, that in tuberculous patients, the perforations in the drum, whether spontaneous or the result of paracentesis, often persist after the middle ear has become dry.

Treatment of Slow Healing Perforations: When a perforation remains open, after the middle ear has dried, the edges of the wound must receive attention. We endeavor to freshen the edges by gently rubbing them with a delicate sterile probe to produce bleeding. The occasional application of a 50 per cent. solution of lactic acid to the edges of the perforation wound tends to retard excessive granulations at the edges and to promote healing. The ear should not be douched after the suppuration has subsided, but it is advisable to insert a sterile cotton plug in the meatus to protect the ear against the introduction of dust and micro-organisms.

Value of the Operation: The profession, with few exceptions, is united regarding the value of this procedure. The number of persons who have been spared mastoid involvement and its consequent dangers are legion. In view of this, it is surprising to say the least, to find *Zaufal* and some of his followers maintaining that paracentesis is not of such great value, as they believe that mastoiditis is not the sequela of pus retention in the tympanic cavity, but of other etiological factors. These observers include among such factors, the variety of the infection in a given case, its manner of development, the local anatomical relations and the patient's general health. Their view, as analyzed by *Heine*, is that the mastoid becomes diseased simultaneously with the involvement of the tympanic cavity, and must eventually be subjected to operation, if the pathological process becomes severe. This group of observers hold that the performance of paracentesis—that is—the opening of one cavity or recess in a case where the anatomical structure demonstrates a multi-cellular abscess, can have no value. Hence they conclude that the value of paracentesis is overestimated.

Experience has shown that in a certain number of cases, mastoid involvement is present at the very commencement of the middle ear suppuration. On the other hand, we have observed a great many middle ear suppurations which either never present any signs of mastoid involvement during their entire course, or the symptoms of mastoiditis are present only at the beginning of the middle ear trouble, subsiding as soon as the tympanic cavity has evacuated its purulent contents. Cases

such as the latter, cannot fail to impress upon any competent observer, that the contentions of *Zaufal* and his school are not in accord with the clinical facts.

Paracentesis is, undoubtedly, of great value in emptying the purulent contents of a suppurating tympanic cavity; in checking the spread of suppuration toward the mastoid; in preventing intracranial complications, especially in childhood; in preventing the burrowing of pus into the neighboring parts—in infants, through open sutures—and in other patients along lines of least resistance.

Immediate Effects to Be Expected: We expect to find a prompt remission of pain following paracentesis; and in cases exhibiting a rise of temperature, a prompt fall of the temperature curve to the normal. Clinically, we find the results somewhat variable, but as a general rule, these expectations are realized. The exception is to be found in infancy and childhood, where occasionally fever will be found to persist for twenty-four hours after operation. Among adults, persistence in the temperature for a like period should always be viewed as suspicious of involvement of the mastoid cells.

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CHAPTER III

AURAL POLYPS

Classification of Polyps—Site of Origin—Significance—Diagnosis and Differential Diagnosis—Preparation of the Patient —Anæsthetic—Operation—After-treatment and Results.

By aural polyps we mean neoplastic formations, which usually spring from some point of the middle ear or the external auditory canal. They are often pedunculated, and histologically are composed of soft connective tissue covered with an epithelial layer. These polyps are visible as more or less rounded masses lying in the external auditory canal. (Fig. 8. Plate III.)

By granulations or polypoid proliferations, we mean inflammatory tissue formations which spring in irregular masses from either the interior of the tympanic cavity and present through a perforation in the membrana tympani, or which emanate from the edges of a perforation in the membrana tympani. The latter type is often designated as polypoid proliferations. (Fig. 9. Plate III.) Both polyps and polypoid proliferations occur in otitis media purulenta chronica.

From being scarcely noticeable, polyps vary in size to such an extent that they may completely fill the tympanic cavity and encroach upon and even destroy the cochlea, *Bōke* (1). They sometimes extend outward into the external auditory canal to the meatal orifice, and are visible at the concha.

Classification: *Steinbürgge* (2) classifies polyps as follows:

1. Granulation growths of mucous or round-cell type;
2. Fibromata;
3. Myxomata.

The fibromata and myxomata are of comparatively rare occurrence; thus *Brühl* (3), examining sixty aural polyps, finds

the granulation type present forty-seven times, the fibromata eight times, and the myxomata only three times.

Occasionally, the polyp may be of a cystic type, fluid having been demonstrated within the capsule; *Urbantschitsch* (4) reports choleatomatous masses as occasionally present in the cystic type of aural polyps.

Site of Origin: The root or pedicle of the aural polyp may spring from cutis, from mucous membrane, or from bone. Although rarely found in acute middle ear suppurations, *Schwartze* reports having observed polyps growing from the edges of a paracentesis wound in the drum.

The point from which the polyp originates should be as accurately determined as possible in every case. They usually arise from within the tympanic cavity, the pedicule extending through the defect in the drum, and the polyp mass proper lies within the external auditory canal. Occasionally the point of origin is the upper pole of the drum, or the external auditory canal walls. In the latter instance, the site of origin will usually be found to be the canal roof, at a point where it merges into the posterior superior quadrant of the membrana tympani.

The mastoid antrum, *User* (5), the tegmen tympani, *Haug* (6), the dura, *Toynbee* (7), and the ostium of the Eustachian tube, *Voltolini* (8), are rare sites from which polyps have been reported to have originated.

Significance: The occurrence of granulation tissue or aural polyps is always suggestive of bone necrosis, *Dench* (9) maintaining that the appearance of granulation tissue in ears, which have been kept thoroughly cleansed, or the recurrence of granulations after their removal, is almost pathognomonic of diseased bone.

Ear polyps, or granulations, when observed in chronic middle ear suppurations, are significant as evidence of lack of cleanliness and care; or when recurring during the course of a chronic middle ear suppuration, which is under competent observation and is receiving proper attention, then the presence of granulations signify the advent of bone necrosis.

The diagnosis of the presence of polyps usually presents but very little difficulty. The mass, upon examination, is found to

be hard and rounded, or papillary in outline. The employment of a probe demonstrates its motility. When either on account of nervousness or pain on the patient's part, or because of inexperience in the use of the probe, this instrument is not employed, the *Seigle* otoscope will serve to demonstrate mobility in the masses. With the exception of a small foreign body in the ear, there is no lesion which will move about under the use of air condensation and rarefaction as a polypoid growth does.

The employment of the ear probe is found to be preferable to the use of the otoscope, as it not only shows the mobility of the growth, but as it makes indentations on granulating masses and not upon true polyps, it gives the surgeon information of a differential character, so that the therapeutics indicated may be applied.

Aural polyps must be differentiated from marked bulging of the membrana tympani, from abscess formations and from exostoses in the external auditory canal. They must also be differentiated from granulations emanating from opened furuncles and from carcinomata of the middle ear.

Differential diagnosis between bulging of the drum and aural polyps depends upon information elicited from the history of the case—absence of pain—the presence of long-standing otorrhœa, and the findings obtained by the use of the probe. Abscesses and exostoses are likewise cleared up by the use of the probe. In abscesses, the history of pain of short duration is significant of the condition. In carcinoma of the middle ear, the neighboring lymphatics are usually involved; this involvement of the lymphatics is invariably absent not only in polypoid proliferation, but also in the aural polyps. Polypoid proliferations and middle ear carcinomata have two symptoms in common—both are indented by the probe, and both readily bleed when the probe, roughly handled, comes into contact with their surface.

Indications for Operation: Wherever polyps are demonstrable, they should be eradicated as completely as possible, as their bulk not only rapidly increases, but may become so large that it blocks the external auditory canal, preventing therapeutic access to the middle ear, and, favoring pus retention.

We have repeatedly observed a persistent otorrhœa rapidly

subside after the removal of the obstructing polyp, and the application of rational local therapeutics. Furthermore, composed of loosely formed connective tissue, aural polyps easily undergo retrogressive changes, and the cell detritus thus found in the middle ear from these changes is a fruitful soil for bacteria propagation. The tendency to secondary infections of the tympanic cavity and of acute exacerbations of chronic middle ear diseases is thus increased by the presence of aural polyps.

Preparation of the Patient: The external auditory canal is thoroughly cleansed of all secretions, a solution of bichloride of mercury (1:2000) being used, followed by an instillation of a solution of cocaine (10 per cent.). The cocaine anæsthetizes all the mucous membrane, and permits easier instrumentation. Nervous women and unruly children are best operated upon under a general anæsthetic. Nitrous oxide gas or ethyl bromide are usually sufficient, although for those who are inexperienced in aural surgery, the administration of chloroform or ether may be necessary, as both nitrous oxide and ethyl bromide anæsthesia is of brief duration, placing but a short time at the disposal of the surgeon. The operation is best performed with the patient in the erect posture; general anæsthesia makes the recumbent posture a necessity.

The Operation: The patient in position, the ear anæsthetized, and the head fixed, we proceed to the removal of the polyp. Under full illumination, a wire snare is carefully introduced into the external auditory canal. The wire is bent in such a manner that it passes over the pedunculated mass of the polyp and slips along the pedicle, and becomes tightened as we push the snare along the pedicle toward the site of its origin, which has been previously carefully ascertained. When the shank carrying the wire cannot be pushed further inward, the loop is drawn tight, and the mass is severed by a slight tug on the instrument. The wire used in making the loop should be selected so as to be as thin as practical without sacrificing rigidity sufficient to keep it in the given form after impinging upon the polypoid mass. Following the removal of the polyp, there usually ensues more or less hemorrhage which, however, is readily controlled. The ear is then douched with antiseptic solution. The stump left

now requires attention; it usually should be cauterized. This is best done by applying to it a pearl of chromic acid fused upon the end of a probe or applicator. The activity of the chromic acid is limited by a douche of sterilized water.

Nitrate of silver, caustic potash sticks, copper stick have all been used in the treatment of aural stumps, but experience has shown us that the most satisfactory results are obtainable from the chromic acid fused on a probe.

Where the polyps are small, or where their base is broad, or where the condition is such that it becomes designated as that of polypoid proliferations, or exuberant granulations, then instead of using the wire snare as described above, curettes may be employed to remove the masses. Occasionally, the Hartman forceps will be found serviceable in these conditions.

The after-treatment, namely, the application of fused chromic acid crystal to the base from which the mass has been removed, is similar to that followed when the removal is accomplished by the snare.

After-treatment: Following the removal of the polyp and the cauterization of its stump, a sterile strip of narrow gauze is introduced into the external auditory canal and kept *in situ* for at least twenty-four hours. The condition of the stump governs the subsequent treatment of the case. Occasionally repeated applications of the chromic acid is necessary before the field is cleared of granulations.

Dangers: As a rule, the removal of aural polyps and granulations presents no dangers when ordinary care is exercised. It is of importance to remember that no pulling force should be used in extracting the polyp caught in the snare. The pedicule must be cut by the wire as close as possible to its point of origin, and under no circumstances should it be pulled out, for the point of origin may be remote from the region attacked by the snare, and serious damage thus may result from the use of force.

In granulations in the region of the fenestra ovalis, both snare and curette require careful and skillful handling so that the stapes is not dislocated, or the facial nerve injured by the curette. The facial nerve and the footplate of the stapes are here in intimate relations.

In polyps presenting a long pedicule, it is a safer procedure first to remove the redundant mass, and at later sittings, to remove the pedicule as far as it is accessible from the external auditory canal.

In conclusion, although polyps are significant of underlying bone necrosis, it will be found that their removal permits freer access to the tympanic cavity, allows better drainage, and that many cases of persistent purulent otorrhœa speedily clear up and the middle ear eventually becomes entirely dry under subsequent rational local treatment.

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CHAPTER IV

OPERATIONS TO IMPROVE HEARING IN DRY MIDDLE EAR LESIONS

Introductory—Exploratory Myringotomy, Indications, Technique, Dangers, Effects—Tenotomy of the Tensor Tympani, Historical, Purposes, Technique—Division of the Anterior Malleus Ligament—Division of the Posterior Fold of the Membrana Tympani—Division of Intratympanic Adhesions —Dangers of the Above Procedures—General Conclusions.

Introductory: For the relief of annoying tinnitus, high degrees of deafness, and occasional vertigo, which occur as the result of pathological changes due to dry chronic middle ear catarrh, surgical measures are employed after all other therapeutic measures fail to afford relief. While in carefully selected cases, as a whole, benefit has followed, the results obtained have not been sufficiently satisfactory to warrant surgical treatment. Various operations have been more or less in vogue at different times in the past, but have fallen into disuse on account of the uncertainty of their results. In passing, it is well to remember that the labyrinth must be demonstrably free of disease in all cases in which these operations are attempted. Local anæsthesia, administered as described in the chapter on ossiculectomy, is usually necessary. The preparation of the patient is similar to that employed for ossiculectomy.

Exploratory Myringotomy: Indications: When it becomes desirable to inspect the tympanic cavity in order to determine the presence or absence of inflammatory adhesions, which inhibit the physiological play of the ossicles and membrana tympani: when it is desirable to locate adhesive bands whose presence is known; when it becomes desirable to determine accurately the degree of ankylosis of the ossicular joints; under these conditions the operation is indicated.

The operation, as a matter of fact, is rarely called for. Adhesive bands can be determined with a fair degree of accuracy by

other means, and ankylosis of the ossicular joints rarely demands inspection to substantiate its presence.

The Operation: The patient properly prepared and anæsthetized, sits in the upright position, with head fixed, and the operative field under full illumination. A flap is cut into the membrana tympani at the point of its surface which overlies the structures to be inspected. The niches of the round and the oval windows, and the incudo-stapedial articulation so often require inspection, that the flap is usually placed in the posterior segment of the drum.

A sharp tenotomy knife is introduced through the drum at the point where the posterior fold merges into the peripheral margin of the drum. The blade is directed toward the malleus, carrying the incision from the point of introduction across the drum toward the processus brevis. At the malleus handle, the knife is turned downward, incising the drum along the posterior malleal margin to the umbo, then the knife is withdrawn. A triangular flap has thus been cut, which upon falling outward, exposes the oval window, the stapes and the incudo-stapedial articulation. Hemorrhage is controlled by applying pledgets of cotton moistened with adrenaline solution (1:1000). Occasionally the triangular flap is insufficient for free inspection, and then it becomes necessary to modify the procedure. The knife is again introduced at the original starting point of the first incision, and is carried downward along the posterior drum margin, incising the membrana tympani, parallel with the annulus tympanicus, for a sufficient distance to accomplish the desired inspection. The lengthening of the incision downward brings the round window into the exposed field.

The cautious use of the probe, carefully introduced behind the malleus, determines the presence or absence of adhesive bands. The motility of the stapes may likewise be ascertained. Sometimes the entire stapes is hid in a fold of mucous membrane, in which event, the enveloping membrane must be cut open to bring this ossicle into view.

Dangers: The knife should never be introduced to such a depth that its point impinges upon the labyrinthine tympanic wall, because in addition to injuring the lining mucosa, it renders

the incision more painful and may disarticulate the stapes or rupture its annular ligament. When the incision is placed too high, the chorda tympani is often cut; this also occurs when the nerve runs lower than normal, extending below the free margin of the posterior fold. Disturbances of the sense of taste on the affected side follow.

After-treatment: When the purposes of the exploration has been accomplished, the flap is carefully replaced into position, and according to a recommendation from *Dench*, is held in place by small pieces of thin paper, which previously sterilized, are carried into position and placed so that they stick on the drum, overlying the line of incision. The canal is lightly packed with sterilized gauze, which is removed after twenty-four hours. Insufflations of aristol or boracic acid constitute the further after-treatment.

The line of incision is usually found healed in a few days.

Tenotomy of the Tensor Tympani: Historical: This procedure was first proposed by *Hyrtl* (1), who held the operation indicated when long-continued spasm of the tensor tympani was present. *Tröltsch* (2) published indications for this operation upon anatomical and pathological grounds, and many modes of procedure were worked out upon the cadaver. It was not until the publications of *Weber-Liel* (3) appeared in 1868, that tenotomy of the tensor tympani became an accepted procedure in otological surgery. Following this lead, *Gruber* (4), *Frank* (5), *Urbantschitsch* (6), and others, reported cases upon which they had successfully operated.

Purposes of the Operation: As advocated by *Weber-Liel*, the operation is performed for the relief of a contraction of the tensor tympani muscle. The spasm of the muscle brings in its train a retracted drum, drawing the malleus handle at an abnormal angle toward the promontory, at times so much so as actually to bring it into contact with the labyrinthine tympanic wall.

From such a condition there results a loss of physiological play in the ossicular chain with consequent loss of sound conduction. Unfortunately for the successful outcome of the operation, the spastic retraction of the lower tendon is usually accompanied by other pathological changes within the tympanic cavity, and

therefore the relief which the operation affords is counteracted by the other pathological lesions usually present, such as adhesive bands, ankylosis of the ossicular joints, etc. When the tensor tendon is severed early in the course of the disease, before adhesive bands have formed, or before ankylosis has developed, better results are obtained from the operation; but as other therapeutical measures are usually, and quite properly, administered for a long time before the patient submits to tenotomy, the development of pathological adhesions has already taken place. Meanwhile, the inactivity of the ossicles tends to ankylosis of their articulations, even if no constitutional causes add contributing factors.

Operative Technique: The patient prepared and anæsthetized with local anæsthetic (see ossiculectomy chapter); head firmly fixed, and with the field of operation in full illumination, the operation begins. For the anatomical relations see Fig. 10.

The tendon of the tensor tympani is accessible either from in front, or from behind, the malleus handle. It is optional with the surgeon to make his incision from below upward or from above downward, in either route of approach. The conformation present in the given case usually governs the selection of the technique employed. The incision is made with a tenotome, the one designed by *Hartman* being recommended.

From in Front, Cutting Downward: The tenotome is introduced into the tympanic cavity through an incision made in the drum, a little in front of the processus brevis. The knife is brought downward until it is felt to impinge upon the tensor tendon. The exertion of a slight degree of pressure severs the tendon. The knife is then carefully withdrawn.

From Behind, Cutting Downward: The tympanic cavity is entered by a tenotome through the drum, immediately behind the processus brevis of the malleus handle, the blade being kept in close proximity to the manubrium mallei. Gradually bringing it down, it is felt to impinge upon the tendon, which is severed with the exertion of slight pressure. The knife is then withdrawn.

From Behind, Cutting Upward: Selecting a point just posterior to and a few lines below the processus brevis, the blade

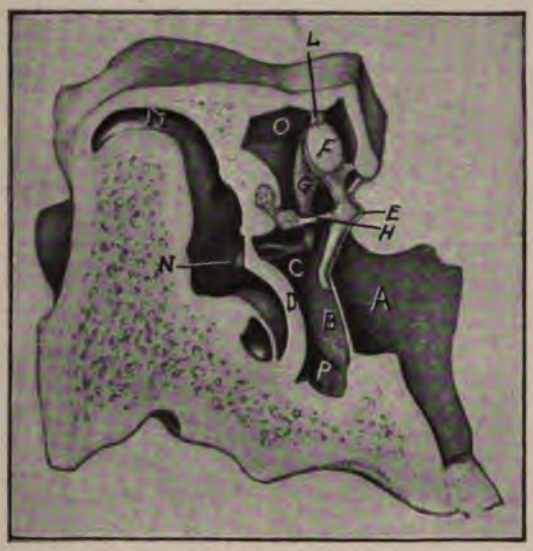

FIG. 10.—PARTLY SCHEMATIC DRAWING FROM SPECIMEN (*after Siebenmann*).

A, External Auditory Canal. B, Posterior Surface of the Drum. C, Tympanic Cavity. D, Promontory. E, Short Process of Malleus. F, Malleus Head. G, Incus. H, Tensor Tympani Tendon. L, Suspensory Ligament of Malleus. M, Superior Semicircular Canal. N, Footplate of Stapes Seen from Behind.

PLATE IV

is introduced and kept closely applied to the back of the manubrium mallei. The blade is slightly rotated until it makes contact with the tendon, when with a slight exertion it is cut. The knife is then withdrawn.

From in Front, Cutting Upward: The knife blade is introduced through an incision anterior to, and a little below the processus brevis. Hugging the surface of the manubrium mallei, the tendon is cut by rotating the knife blade upward.

In all these procedures, the sensation imparted by the knife when it comes into contact with the tendon of the tensor must be recognized by the surgeon. A characteristic click is both felt and heard as the tensor is cut through.

Occasionally, tenotomy of the tensor tympani is called for in cases already presenting a perforation. This so far modifies the procedure that the knife is introduced through the existing perforation, severing the tendon by rotating the blade in the direction required to reach the tensor with its cutting edge.

In discussing the purposes of the operation, we commented on the results of the procedure.

Division of the Anterior Malleus Ligament: This operation is rarely indicated, and when performed, is usually unsuccessful. It is called for in cases presenting marked retraction of the drum, with a high degree of deafness. The object of the operation is to permit the drum to assume its normal position. After anæsthetization, the membrana tympani is incised with a short curved tenotome, just anterior to the processus brevis, carrying the incision through the anterior fold upward and outward toward the margin of the membrana tympani. As the knife is pressed through the anterior fold, it severs the anterior ligament of the malleus. The after-treatment consists of repeated insufflations of aristol or other antiseptic powder.

Division of the Posterior Fold of the Membrana Tympani: In cases presenting a high degree of deafness, accompanied by intense tinnitus, where the drum presents a marked retraction with the manubrium mallei foreshortened, and where the posterior tympanic fold is stretched across the upper posterior portion of the drum as a markedly distinct prominence, in these cases the incision into and through the posterior fold is indicated to relieve

tension, and to permit the return of the drum to its normal position. As the retraction is usually not due to tension of this fold alone, the operation rarely offers more than temporary relief. The knife is introduced at a point just posterior to the processus brevis, and the incision is made by carrying the knife obliquely upward through the tense posterior fold. The after treatment consists in aristol insufflations.

Division of Intratympanic Adhesions: The presence of intratympanic adhesions not only tends to render the ossicular chain immobile, but they often assist in retaining the membrana tympani in a retracted position, acting with the tensor tendon to nullify the drum's elasticity, and to impede functional activity. These bands are usually the result of middle ear suppuration which finally becomes dry; or they are the sequelæ of inflammatory processes around the footplate of the stapes. The presence of these bands calls either for their removal, or their division, to free the ossicles and the drum from the restricting attachments. Necessarily, the technique in the given case is dependent upon the pathological factors present. *Dench* divides these adhesions into two classes: those about the stapes and those spanning the tympanic cavity between the various ossicles and the tympanic walls.

Furthermore, these adhesive bands may be classified in groups as follows: (A) Where they involve various sections of the sound conducting apparatus (usually the non-suppurating cases); (B) Where a large perforation exists whose margins are involved in the adhesive processes; (C) Where only a remnant of Shrapnell's membrane is present, or where only the posterior superior quadrant of the drum remains, whose edges are thickened and take part in the adhesive band formations, which usually involve the ossicular chain.

In the cases wherein the adhesions involve the conduction apparatus, the membrana tympani is generally found intact. Close inspection demonstrates the location of the bands.

The incision is made through the drum so as to render the bands accessible to the knife. No hard and fast rule of procedure is possible. Following the incision into the drum, a tenotome is introduced and the adhesive bands severed. Antiseptic powders are insufflated to complete the procedure.

In cases involving the stapes head, the tendon of the stapedius is sought for, recognized and cut. The severed end is grasped in a small mouse-toothed forceps and used as a guide to the head of the stapes. Adhesions running laterally pull the stapes to one side out of the visual field. The tenotome is carried posteriorly close to the tympanic ring, and these bands are cut, incising from above downward.

Short incisions arranged in a radiating zone are advocated by *Dench*. We have not always found this easily accomplished. The adhesions anterior to the head of the stapes are not cut. The parts retract, freeing the stapes. Insufflations of antiseptic powder complete the technique.

Where a large perforation is present, whose margins are part of the adhesive process, we separate the adhesions of the perforation edge from its attachments with a small bent knife. The malleus tip is freed and the handle loosened.

The procedure differs according to the location of the bands. If adhesion is noted at one particular point, a circular incision may be made around it and the entire fibrous mass of tissue removed.

In the cases where portions of the drum remain (Shrapnell's membrane, with thickened, dense fibrous edges continuous with the adhesive bands), it usually suffices to incise the thickened edge with a tenotome, carrying the incision into the membrana tympani at right angles to its edge for a distance sufficient to relieve tension.

Dangers of these Procedures: During the performance of the operations detailed above, there is danger of injuring the labyrinthine windows with the tenotome. No unnecessary force must be applied during instrumentation. Knives should be sufficiently sharp to sever bands of dense fibrous tissue without resort to force; neither should the lining mucosa of the posterior tympanic wall be impinged upon by the point of the knife unnecessarily. If this happens, it renders the procedure more painful and increases the amount of hemorrhage. Injury to the labyrinthine windows may entail unpleasant sequelæ.

Conclusions: In conclusion, personal experience teaches us that these procedures, when carried out singly, rarely produce

the desired effects. We do not recommend them, but prefer the performance of ossiculectomy in those cases of severe tinnitus, with high degree of deafness and the presence of constraining bands. Ossiculectomy removes not only useless ossicles, but permits the freeing of the stapes from retaining adhesions, and allows transmission of sound waves direct to the labyrinthine capsule. This procedure is preferable to the retention of a drum partially or wholly cicatrized and ossicles more or less ankylosed.

We have purposely omitted a description of the operation for the removal of the stapes—stapedectomy. We hold the removal of this ossicle to be unjustified, and always dangerous. Upon its removal severe symptoms supervene almost immediately, viz., distressing vomiting and dizziness, besides the potential danger of labyrinthine infection and the subsequent development of intracranial complications. Considering these sequelæ in the light of the universally unsatisfactory results obtained in our efforts to improve hearing, we are of the opinion that the operation of stapedectomy is unsafe and dangerous and should never be attempted.

REFERENCES

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(4). Gruber, Monatschrift für Ohrenheilkunde, No. 4, 1873.
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(6). Urbantschitsch, Lehrbuch der Ohrenheilkunde.

CHAPTER V

OSSICULECTOMY

Historical—Anatomical—(The Internal Drum Surface; The Tympanic Cavity; The Aditus ad Antrum; The Ossicular Chain)—Indications for the Operation—Advantages of the Operation—Preparation of the Patient—Administration of Local Anæsthetic—Operation—After-treatment—Dangers of the Operation—Value of Ossiculectomy.

The operation of removing the malleus and the incus together with such portions of the membrana tympani and the lateral aditus wall is erroneously designated ossiculectomy. In reality, it is a modified *Stacke* operation performed through the external auditory canal. The operation finds employment not only as a means whereby chronic purulent conditions of the middle ear are cured, but also as a measure which, in judiciously selected cases, improves the hearing where the so-called dry catarrhs and otosclerotic lesions have been diagnosed. Finally, in cases where inflammatory adhesions become organized and result in permanent adhesions, and thus render the ossicular chain useless, the operation has been found of benefit.

Historical: The earliest authentic record of the performance of this procedure is that of *Himly* and *Cooper*, 1800–04, both of whom attempted to improve hearing by the operation, limiting themselves, however, to a partial excision of the membrana tympani. In 1841 *Fabrizi* used a similar procedure. Because of the transient nature of the improvement obtained, the operation soon fell into disuse, but was revived in 1863 by *Gruber* (1), who included among the benefits derived from it, the relief of tinnitus aurium. *Wreden* (2) designated the procedure "sphyrotomy," and in performing the operation, removed the malleus handle in addition to excising portions of the drum. His efforts were directed toward maintaining a permanent opening in the membrana tympani.

Schwartze (3) observing that where nature spontaneously evicted one or more of the ossicles in cases of chronic suppuration hearing remained good, conceived the idea of removing the drum and the malleus, not only in an effort to improve hearing, but also to benefit the suppurating ear. The credit of having been the first to establish ossiculectomy upon the fundamental basis upon which it rests to-day, belongs to *Schwartze*, 1873.

Kessel (4), in 1878, advanced a step further in the procedure, when he advocated the removal of the posterior part of the drum, and the resection of a portion of the sulcus tympanicus. He also attempted extraction of the stapes, but in the latter procedure, not only were untoward symptoms the result, but the expected improvement in hearing failed to be realized and the procedure was abandoned. From 1879, the surgery of the ossicles became general; *Lucae* (5), *Sexton* (6), *Stacke* (7) published records of cases operated upon. In 1890, *Ludwig* (8) demonstrated that a large percentage of chronic ear suppurations were due to necrotic conditions of the incus, and he therefore recommended that this ossicle as well as the malleus should be removed in suppurating cases. To this suggestion, *Stacke* added the removal of the external (lateral) aditus wall.

From this time ossiculectomy took its place in otological surgery and began to have universal acceptance (*Dench* (9), *Richardson* (10), *Grünert* (11), *Luc* (12), *Ludwig* (8), *Burnett* (13), and others.

We owe it to the suggestion of *Gomperz* (14), that local anæsthesia is employed in ossiculectomy. He first recommended the anæsthetization of the parts by injecting the walls of the external auditory canal, a method which has recently been successfully perfected by *Neumann* (15).

Anatomical: In sketching briefly the anatomy of the region affected by the operative procedures in ossiculectomy, we are not describing the anatomy of the drum and tympanic cavity in full, but we are rather emphasizing the points whose relations are of importance, not only for the correct performance of the operation, but also for the avoidance of the dangers which accidental injury to the important anatomical structures would entail.

The Internal Drum Surface: The internal drum surface, that is, that surface which is turned toward the tympanic cavity, is covered with mucous membrane. Its configuration is similar to that described in the anatomical notes on paracentesis for the configuration of the outer drum surface. The malleus handle, however, projects more sharply on the tympanic side, its chief bulk being on this side of the drum. (Fig. 11.) The upper marginal zone is hidden by the malleus and the incus and by two narrow mucous folds which pass horizontally. These folds, designated the plicæ malleolaris anterior and posterior (by many called the folds of *Tröltsch*) present themselves as prominences in the tympanic cavity, one of which is situated in the anterior superior and the other in the posterior superior quadrants respectively. They are attached to the upper portion of the malleus handle, from which they arch upward anteriorly and posteriorly respectively, in the free plane of the internal drum surface, being inserted near the bony margin of the membrana tympani. The anterior fold is lost on the malleus handle at the level of the tensor tendon, while the posterior fold reaches a somewhat lower point.

The free margin of the folds is directed downward, and between the arched membranous folds are two pockets designated the recessus membrana tympani anterior and the recessus membrana tympani posterior. The chorda tympani passes across the inner surface of the posterior recess; in the newborn in addition the long process of the malleus also passes in the posterior pocket. Occasionally the posterior recess communicates with the recessus membrana tympani superior (*Prussak's* Space) at its anterior end, that is, at a point very close to the handle of the malleus. The chorda tympani passes in front of the anterior tympanic recess (posterior pocket) at its posterior portion, and finally after crossing the tympanic cavity from its outer to its inner wall, enters the canalis Fallopii by a special channel, near the posterior superior margin of the tympanic ridge (*Bardeleben*). Occasionally the chorda tympani is found isolated, running below the free margin of the posterior fold, passing from the tympanic margin to the malleus handle, or running along the malleo-incudal articulation.

Often a few thick or several thin cords of dense fibrous tiss are observed extending through the posterior recess.

At a point above the processus brevis, the malleus hanc inclines away from the internal drum surface, a series of muco membrane folds forming a loose connection between them, a incidentally a number of hollow spaces. These reduplicatio of the mucous membrane on the internal surface of the dru cover the membrana flaccida in a way similar to that in whi the *Tröltsch* folds are arranged upon the upper internal surfa of the pars tensa. To judge by the differing accounts given these folds by *Prussak*, *Kretchmann*, *Politzer* and *Siebenman* they vary considerably both as to extent and configuratio The drum forms the outer (lateral) wall of the tympanic cavit

The Tympanic Cavity: The tympanic cavity is described a flattened cylinder; to facilitate description, we speak of i outer (lateral) wall, its inner (mesial) wall, its anterior and i posterior walls, besides a roof (upper wall) and a floor (low wall). (Fig. 11.)

In detail, we find that the outer (lateral) wall separates th tympanic cavity from the external auditory canal. This wa consists of the membrana tympani and its bony framewor The inner (mesial) wall, often designated the labyrinthine wal separates the tympanic cavity or middle from the internal ea The anterior wall is made up largely from the ostium of th Eustachian tube. The posterior wall separates the tympani cavity from the mastoid process.

Lying above the tympanic cavity is a space opening into th antrum mastoideum, to which *Bezold*, *Tröltsch* and *Siebenman* have given the name aditus ad antrum. An actual bony wa bounds the tympanic cavity above only in its anterior par the posterior part being really an open space filled in by th malleus and the incus. This space, the recessus epitympanicu (aditus ad antrum) is marked at its upper boundary on th drum, by the insertion of the axis ligament of the malleus. It boundary on the labyrinthine wall is marked by the fibrous an mucous bands which span the space horizontally, and whic run to the tendon of the tensor tympani, while at a more pos terior point, the horizontal semicircular canal and the faci

crest mark the boundary line between the aditus and the tympanic cavity.

The tympanic cavity is spanned by the tendon of the tensor tympani muscle, and the ossicular chain, although the greater part of the bulk of the incus and the malleus lies in the aditus ad antrum. (Fig. 11, G, F.)

Let us take up the walls of the tympanic cavity in order, so as to describe their surgical-anatomical details:

The lateral (outer) wall, sometimes known as the paries membranacæ, is made up of the drum and its osseous frame. (Fig. 11, B.) That portion of the upper drum margin formed by the squamosa is considered as belonging to the lateral wall of the aditus. It is, however, continuous with the lateral wall of the tympanic cavity.

We have already described the membrana tympani in the chapter on paracentesis, to which the reader is referred.

The anterior tympanic wall (paries corotica), is in evidence only at the lower half of the tympanic cavity, presenting itself as a narrow wall about 4 mm. in height. Often this narrow strip of bone contains a few pneumatic cells arranged in a radiating zone. The upper half of the anterior wall presents the ostium tympanicum tubæ, and is about 4.5 mm. high. The floor of the Eustachian tube meets the anterior tympanic wall at an angle of about 90°. Small canaliculi often are present at the anterior wall, and occasionally dehiscences are observed, uncovering small areas of the carotid artery.

The tympanic floor (paries jugularis) merges gradually into both anterior and posterior tympanic walls. *Kretschmann* has designated this region as the recessus hypotympanicus. (Fig. 11, P.) The tympanic floor separates the tympanic cavity from the jugular bulb; it is often pneumatic and presents ridges extending from its outer to its inner sides. Occasionally, there are dehiscences in the tympanic floor; these bring the jugular bulb into direct contact with the mucous membrane lining the middle ear.

The posterior tympanic wall (paries mastoidea) rises from the floor of the tympanic cavity in a slight curve like a bow, presenting at its upper limit a small series of pneumatic cells desig-

nated by *Schwalbe* (16) the sinus posterior. Limited below by a square ledge of bone, it merges toward the median line into a pyramidal eminence from whose lateral end a small bony canal is found running toward the facial canal. Deep on the posterior tympanic wall, the facial canal runs its course behind the eminentia stapedii.

The mesial tympanic wall (paries labyrinthica), separates the tympanic cavity from the internal ear, and joins the middle and the internal ear through the labyrinthine windows.

The middle of the mesial wall presents a somewhat round protuberance—the promontory. (Fig. 11, D.) This is a flat, hard, bulging bone, about 8 mm. in width and 6 mm. in height, formed by the basal turn of the cochlea. Toward the tympanic cavity it presents a smooth surface; anteriorly the promontory merges into the wall of the Eustachian tube. At a lower level anteriorly, the promontory is lost in the tympanic floor. Posteriorly, below the fenestra rotunda, and posteriorly above, the fenestra ovalis are situated.

The upper tympanic wall (roof) is the tegmen tympani (paries tegmentalis) which separates the tympanic cavity from the middle cranial fossa. It is slanting in direction, and runs from below, anteriorly, upward posteriorly. It presents the petro-squamous suture.

The tegmen tympani is often formed of a very thin plate of bone, having numerous low, small-sized pneumatic cells. Very often dehiscences in its structure are found, in which event the dura is in direct contact with the mucosa of the pneumatic cells, or with the lining mucous membrane of the tympanic cavity.

Aditus ad Antrum: While the aditus becomes of more importance when discussing the surgical anatomy of the middle ear and the mastoid, we believe that here a brief description of this anatomical structure is in order, since the greater bulk of the ossicular chain lies in this space.

The aditus ad antrum (attic, epitympanic space) is shaped somewhat like a triangular prism, one of whose sides is directed outward and upward, the second, directly upward, and whose third side faces the mesial line of the head. It is, therefore,

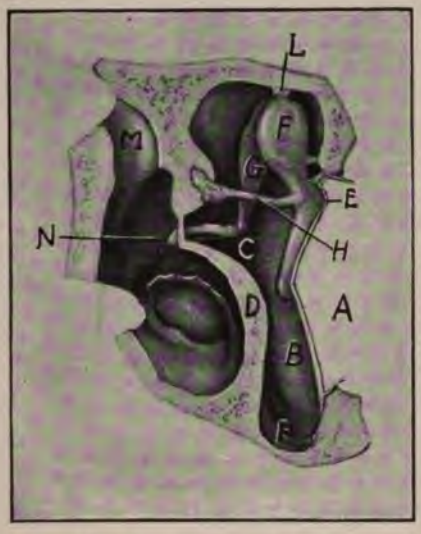

FIG. 11.—PARTLY SCHEMATIC DRAWING FROM SPECIMEN (ENLARGED) [*after Siebenmann*] SHOWING:

A, External Auditory Canal. B, Posterior Surface of Drum. C, Tympanic Cavity. D, Promontory. E, Process Brevis Malleus. F, Malleus Head. G, Incus. H, Tensor Tympani. L, Suspensory Ligament of Malleus. M, Part of Superior Semicircular Canal. N, Footplate of Stapes Seen from Labyrinthine Side.

PLATE V

possible to differentiate between an upper mesial, an upper lateral, and an inferior longitudinal edge.

An extension of the axis of the Eustachian tube outward and upward through the tympanic cavity, in a slight curve so as to arch it, with its convexity upward, gives the longitudinal axis of the prism-shaped aditus. The aditus seems to be the continuation of the tubal axis toward the antrum mastoideum. The aditus ad antrum is bounded anteriorly by the tensor tendon together with a spur of bone (crista transversa), which is seen situated just above the tensor tendon, and which extends transversely below the tegmen. A further boundary is furnished anteriorly by a series of mucous folds, variable in form and extent, which serve to connect the tensor and the so-called crista transversa.

Posteriorly the aditus merges gradually and without differentiation into the antrum mastoideum. For purposes of description, an imaginary boundary is constructed by placing a plane perpendicularly to the longitudinal axis of the aditus, which runs through the posterior and short process of the incus.

The roof of the aditus—the tegmen—presents a dural process which extends to the tympanic cavity. This process of dura is vascular in nature and is situated rather laterally, or to the outer superior angle of the aditus, passing, in the adult, through the remains of the petrosquamous suture, and in children, through the patent suture. The suture, or its remains, is noted as a constant landmark on the tegmen over the aditus.

Laterally, the outer aditus wall is formed from a bony plate which finds insertion between the aditus proper and the inner or mesial end of the osseous external auditory canal. This is a prolongation of the lateral (outer) wall of the antrum mastoideum, and corresponds to the upper wall of the external auditory meatus, as well as to the upper half of the posterior wall of the osseous external meatus. This plate of bone is hard and dense, and is designated by *Walb* and others as the pars ossea.

According to *Kretschmann* and *Siebenmann* (17), that portion of the membrana tympani situated above the processus brevis, is to be considered as part of the lateral wall of the aditus. This arrangement, which places that portion of the drum above

referred to, as part of the aditus rather than as belonging to the tympanic cavity, is furthermore founded upon clinical grounds. It is a common observation to find the membrana flaccida involved when the pathological process is limited to the aditus.

The mesial or inner wall of the aditus is formed of compact bone, the labyrinthine capsule. Approaching the oval window and the region of the mastoid antrum, its surface projects into the cavity proper as a broad ridge. Toward the antrum many small pneumatic cells are present.

The Ossicular Chain: The ossicular chain is lodged largely in the aditus, and partly in the tympanic cavity proper. The malleus, the largest of the three ossicles, is a bone consisting of a shaft and a head joined at an obtuse angle, which is designated the neck. The shaft is prismatic in form, tapering gradually and terminating often at its lower end in a hook-like extremity—the umbo. A bony tubercle, the processus brevis, is present at the junction of the shaft and the neck. It is directed forward and laterally (outward). The prismatic shaft presents its lateral surface for attachment to the membrana tympani. The processus gracilis, in young subjects, springs from the anterior surface of the shaft, from a point just below the short process; in adults, this process lies in the fibers of the anterior malleal ligament. The external surface of the shaft serves as an attachment for the external ligament.

The anterior surface of the head and the adjoining neck are markedly grooved for the insertion of the anterior ligament. Posteriorly, the head of the malleus is encroached upon by its saddle-shaped surface which articulates with the incus.

The incus presents a body and two processes, the shorter or horizontal one really being the continuation of the body. This process is conical, extending toward the back of the head, and resting its top in a minute niche in the posterior tympanic wall. The body of the incus, flattened from before backward, is twice as long in its vertical as in its transverse diameter. Its anterior surface articulates with the head of the malleus. The long incus process is a tapering shaft of bone, extending downward and articulating at its extremity with the stapes.

The stapes, the ossicle lying deepest in the tympanic cavity,

is stirrup-shaped, presents a head hollowed for articulation with the process of the incus, and below the head gives off two divergent crura, one longer and more curved (the posterior one) than the other. The crura terminate in an oval-shaped plate of bone—the footplate—which, with its annular ligament, closes the fenestra ovalis.

The entire stapes lies in a depression—the pelvis ovalis, formed above by the side of the semicircular canal and the facial encasement, and below by the protuberance of the promontory. The footplate takes an oblique position in the oval window, lying nearer to the posterior inferior walls of the fossa than to the anterior and superior walls.

Often adhesions between the posterior crus of the stapes and the posterior tympanic wall are observed.

The ossicles are suspended in position by the ossicular ligaments, of which the anterior, the lateral (external), the posterior and the superior (suspensory ligament) are the principal ones. The anterior ligament arises from what *Dench* calls the spina tympanica major, from the Glaserian fissure which some fibers traverse. The fibers converge, passing outward, upward, and backward and find insertion in the outer part of the neck and in the depression on the anterior part of the head of the malleus.

The lateral ligament is fan-shaped, springing from the neck of the malleus, the fibers diverge to find insertion at the free margin of the inner (mesial) extremity of the upper wall of the bony meatus. Part of this ligament, mainly the posterior fibers, is known as the posterior ligament. The lateral portion of the lateral ligament is designated by European anatomists, the axis ligament, or axis band of the malleus. The superior or suspensory ligament is a delicate rounded band of fibrous tissue extending from the malleus head upward toward the tegmen.

The incus finds attachment to the surrounding bony walls by a distinct fibrous band, the posterior ligament, which extends from the short process near its extremity to the labyrinthine wall. The fibers diverge to find insertion, spreading out fan-like, and are often designated the fan-shaped ligament of the incus. The footplate of the stapes is confined to the oval

window by the annular ligament. Finally, both incus and malleus are bound together by a loose capsular ligament, and another capsular ligament encloses the incudo-stapedial articulation.

The stapedius muscle is inserted below the head, at the neck of the stapes, at the juncture of the neck and the posterior crus. This muscle arises from within a pyramidal-shaped bony excrescence on the posterior and the internal tympanic wall, situated in front and just below the aqueductus Fallopii. The muscle fibers form a tendon which, after piercing the apex of the pyramid, is inserted as described above.

The tensor tympani crosses the tympanic cavity. It arises from the cartilaginous portion of the Eustachian tube and from the adjacent part of the great wing of the sphenoid, running in a special bony canal from which some of its fibers take origin; it curves around the processus cochleariformis, after emerging from its canal, then crosses from the mesial tympanic wall to the lateral wall to be inserted into the inner and the anterior surface of the handle of the malleus. A few of its fibers pass for a considerable distance down the handle of the malleus, some spreading to its anterior surface. The muscle tendon takes a course outward, making almost a right angle when changing direction from the mesial to the lateral wall of the tympanic cavity.

The chorda tympani emerges from the aqueductus Fallopii above the pyramid just described, it crosses the tympanic cavity from behind forward, passing between the long process of the incus and the handle of the malleus. It leaves the middle ear through the Glaserian fissure to join the lingual branch of the trigeminus, reaching the Glaserian fissure by the posterior fold of the membrana flaccida.

Indications for the Operation: Summarizing the employment of ossiculectomy, we find the operation indicated in two general classes of cases:

I. To secure an improvement in hearing in the dry catarrhal conditions; and (II) to remove necrotic ossicles and diseased neighboring parts, in order to promote healing by providing easier access to the seat of disease, and by facilitating drainage of the middle ear spaces.

I. In the dry catarrhal conditions, where hearing is greatly reduced and the subjective noises are intense, and where all other therapeutic agents have been unsuccessfully employed, here the operation of ossiculectomy is indicated. It is indicated to remove a useless membrana tympani and its ossicles, to open the route for the sound waves, in order that these may directly impinge upon the labyrinthine capsule and the labyrinthine windows, and thus increase the hearing faculty.

In cases where a high degree of deafness exists, which is the consequence of adhesions between the sharply retracted drum and its malleus handle on the one hand, and the promontory on the other; or where extensive rigid calcifications of the drum are evident; or where, accompanying severe deafness, demonstrable ankylosis between the malleus and incus obtains; in these classes of cases the procedure is indicated.

The operation is, furthermore, indicated in cases having a high degree of deafness where incurable stricture of the Eustachian tube is evident.

II. Ossiculectomy is indicated in suppurative conditions of the middle ear where, after repeated removal, granulations present themselves in the region of the aditus. The operation is of special service in cases where symptoms of pus retention become simultaneously evident with the recurrence of the granulations.

When purulent secretions exude from a perforation situated in Shrapnell's membrane—usually an evidence of obstinate suppuration of the external (lateral) aditus wall—associated with a high degree of deafness; or in cases presenting an obstructed flow of pus emanating from the superior tympanic space, often accompanied by painful swelling of the posterior wall of the external auditory meatus; or in cases presenting a fistulous opening in the posterior-superior quadrant—an evidence of aditus involvement—then ossiculectomy is indicated.

The operation is also indicated where cholesteatomatous masses fill the upper tympanic spaces, inducing frequently recurring attacks of middle ear suppuration. The operation is indicated in all obstinate middle ear suppurations, resistant to all other local rational treatment, and where demonstrable

caries of the two greater ossicles, or of the surrounding osseous walls, is present.

Finally, the operation is indicated as a preliminary to the performance of the radical mastoid operation—a measure which, if successful, may often render the radical operation avoidable.

Regarding this last indication, the reader is referred to the indications for the performance of the radical mastoid operation, where attention is called to a class of cases where there is present persistent purulent otorrhœa, which lasts for a long time, but in which the lesion is confined to the lining mucosa of the tympanic cavity and the Eustachian tube. Experience has shown that in such cases, the radical mastoid operation does not effect a cure of the persistent otorrhœa, but only serves to render the parts more accessible to local treatment; the secretions from the diseased mucous membrane of the Eustachian tube, however, and from the other areas of mucous membrane inaccessible to operative removal, e.g. around the niche of the stapes, continue to suppurate after the radical operation, as long as the mucous membrane lesion remains unhealed. In the chapter referred to, we have given the data to distinguish these cases from those in which the lesion is confined to the bone, and we hold that ossiculectomy is indicated in the former class of cases because it renders the mucous membrane as accessible to local treatment as does the radical operation. Moreover, it gives the same, if not better results, without causing the patient to incur the dangers of a major operation.

Advantages of the Operation: In chronic middle ear suppurations presenting any of the conditions outlined under indications, and in which, either because of pus retention or by reason of the persistence of the purulent otorrhœa, a graver operation —the radical—would have to be undertaken before a cure was effected, in these cases ossiculectomy presents distinct advantages, and should at least be tried before a graver operation is suggested.

Where caries is confined to the ossicles, especially the malleus and the incus, then ideal conditions are presented to effect a cure of the chronic suppuration by this little operation. This procedure carries with it few dangers and usually does not

incapacitate the patient. Since the perfection of the technique of administering local anæsthesia by *Neumann*, of Vienna, the consequent dangers and the untoward sequelæ of a general anæsthetic are avoided. The after-treatment of ossiculectomy is such that the patient is not detained from his usual occupation. Furthermore, when it is remembered that the alternative to ossiculectomy—the radical mastoid operation—is not as devoid of danger to life and to the future welfare of the patient as some of its advocates would have us believe, then the advantages of ossiculectomy will be estimated at their true value, and the operation will find more extensive employment.

Preparation of the Patient: The details of the preparation of the patient vary at the hands of different surgeons. Thus *Heine* (18), in his desire to prevent the production of hyperæmia of the drum and of the mucous membrane, avoids all unnecessary cleansing of the ear and the external auditory canal just prior to operation. He hopes by the avoidance of hyperæmia to lessen the consequent hemorrhage. He advocates the thorough cleansing of the parts twenty-four hours before operation, and bathes the external auditory canal with a solution of bichloride of mercury. Placing a strip of sterile gauze in the auditory canal, he covers the concha with a sterile dressing, held in place by a retaining bandage. *Ballin* (19), on the other hand, cleanses the operative field with a one-half per cent. carbolic acid solution, or with lysol, and follows this by placing a plug of cotton soaked in alcohol or ether in the canal. We usually prepare our patient twenty-four hours in advance. Thoroughly cleansing the ear and the neighboring parts, we wash the external auditory canal with an antiseptic solution, and place a strip of sterile gauze, moistened with an alcoholic soap solution, in the canal, and cover the concha with the same solution, retaining these in place by means of a bandage. The patient is kept quiet for the day previous to operation. If a general anæsthetic is to be administered, as is often necessary in nervous individuals and in children, then the bowels are to be emptied before operation. We use nitrous oxide followed by ether for general anæsthesia.

Regarding the question of anæsthesia, it may be noted that the operation is more satisfactorily performed under local

anæsthesia with the patient in the upright posture. Local anæsthesia is in itself somewhat of a hemostatic, and not only is a better view of the parts obtainable, but the relative anatomical relations are seen in their accustomed position. The administration of general anæsthesia with the resulting congestion to the head, tends to produce a bloody operative field and thus handicaps the operator. However, the question of general or of local anæsthesia must rest individually on the character of the patient. Under local anæsthesia, administered as suggested by *Neumann*, the procedure is absolutely painless.

Administration of Local Anæsthetic: Assuming local anæsthesia to have been decided upon, the patient is placed in the position for examination, upright, with his head fixed against a suitable rest and supported by an assistant. The bandage and dressings are removed, and the neighboring parts again cleansed with an antiseptic solution, alcohol or ether.

The hair of female patients is confined in a sterile towel, and the concha is drawn through a perforated napkin of sterile gauze. The external auditory canal is cleansed, a suitable speculum introduced and the administration of the anæsthetic begins.

Equal parts of adrenaline (1:1000) and a one per cent. solution of cocaine are injected by means of a syringe fitted to a needle slightly longer than the ordinary hyperdermic needle, and bent at an obtuse angle so that the body of the syringe is outside of the field of vision, thus enabling the operator to see the needle point throughout the entire manipulation. The capacity of the syringe should be about 30 minims.

Often a spray of ethyl bromide, applied to the point of introduction of the needle renders this procedure less painful. The needle is introduced into the superior meatal wall, at the junction of the membranous and the osseous portions. (Fig. 12.) This point is demonstrable when the concha is raised and lowered, corresponding to a fold which becomes evident during this maneuver.

Pushing the needle inward horizontally toward the drum, we inject the anæsthetic as the needle point is advanced; a slight infiltrate is seen, immediately succeeded by bleaching. Occa-

sionally as the fluid reaches the middle ear, a few drops of the anæsthetic are observed behind the remains of the drum. Anæsthesia is usually complete after a wait of from five to ten minutes. Experience has shown that the introduction of a pledget of cotton wet with adrenaline (1:1000) into the external auditory canal during this period of waiting aids to control the hemorrhage. It is to be noted that all the above steps are taken under full illumination.

The Operation: The operation starts by placing two inci-

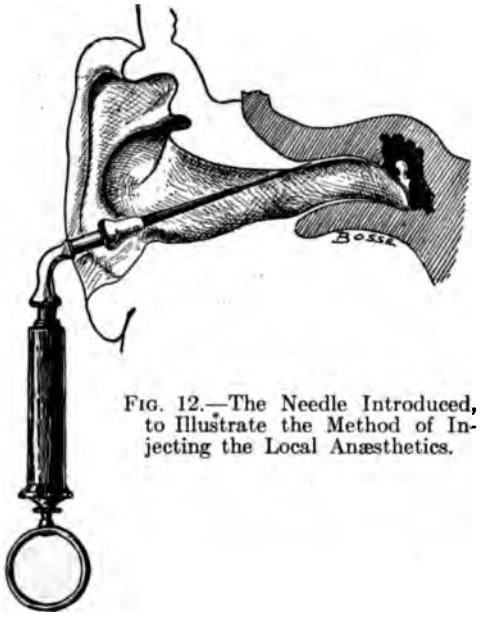

FIG. 12.—The Needle Introduced, to Illustrate the Method of Injecting the Local Anæsthetics.

sions in the drum remains, one on either side of the malleus handle. These incisions are carried upward parallel to the handle of the malleus, as far as the drum margin, a tenotomy knife being employed for this purpose. (Fig. 13, Plate III.)

When the membrana tympani is intact, complete circumcision is advantageously made, and acting upon a suggestion of *Schwartze*, the incision should be carried from below upward, first along the margin at the posterior, and then starting from the same place, continued from below upward along the margin of the anterior half of the drum, both incisions meeting above.

Thus made, the cutting edge of the knife is not only always in full view, but is free from the resultant hemorrhage.

The incised membrana tympani usually curls about the malleus handle. Often when cutting through the posterior fold of the drum, the chorda tympani is severed, especially if the end of the knife is deeply introduced.

The next step in the operation is the extraction of the malleus. In order to extract this ossicle it is necessary to sever the various structures holding it in place. We begin with the tensor tympani, cutting it with an angle-bladed knife, in that portion of its contiguity, which spans the tympanic cavity, severing it between its malleal attachment and the labyrinthine wall of the middle ear.

The angle blade of the knife is introduced through the incision made in the drum, high up near the aditus, holding the shank horizontally as the knife is gradually brought downward until it is felt to impinge upon the tendon of the tensor tympani. A slight pressure cuts the tendon. To prove the success of the maneuver, a probe introduced behind the malleus demonstrates whether the tendon has or has not been severed. Connective-tissue adhesions are severed in a like manner. During these manipulations, care is exercised not to dislocate the stapes. The incudo-malleal articulation is usually easily broken, after which the malleus is firmly grasped with a *Hartman* forceps, or other suitable instrument, at a point just above its neck, and with a gentle rocking motion, which breaks up the connecting bands and tears the suspensory ligaments, the ossicle is carefully removed. The malleus usually comes away easily; the only danger lies in a possible fracture of its neck, in which event, the head remaining *in situ* will defeat the purpose for which the operation is undertaken. *Schwartze*, *Kessel* and others pass a small wire snare around the malleus neck to remove the ossicle. Either this, or the above described manipulation, is applicable.

The removal of the incus follows. The ease with which this is accomplished varies in different cases. Where the incus lies high in the aditus, or is wedged toward the antrum, many obstacles to its easy removal may present themselves. Some observers have reported the incus missing, but our experience

tends to show that notwithstanding long-continued suppuration, although invisible it is usually present, and generally is to be found whenever the malleus is present.

The careful, skillful use of a probe, with its end bent at a right angle, to search the region above the field of vision, demonstrates its presence. Often the search with the probe loosens the incus, and causes it to drop into view, while occasionally only its long process becomes visible. To remove the incus, we use the ring-knife of *Zeroni* (20), passing the ring over the long process, pushing the instrument upward, and gripping the incus by raising the instrument handle. A slight exertion of pressure loosens the ossicle, which is then removed with a forceps. It is rarely necessary to sever the incudo-stapedial articulation. If necessary this is easily accomplished by a curved knife. The loosened incus must not be jammed into the antral opening of the aditus, and care must be exercised that it is not pressed against the facial nerve, or against the stapes, as the use of force would dislocate the latter and cause facial paralysis in the former instance.

Should the dislocated incus drop to the tympanic floor, its subsequent removal often requires great skill, because the tympanic floor covering the jugular bulb is often the seat of dehiscences, and its injury may be followed by unpleasant sequelæ.

The operation of ossiculectomy is completed by removing the lateral (outer) aditus wall. This is not always necessary, but many cases which otherwise would fail to be cured of the otorrhœa will recover if this additional detail is performed. The lateral aditus wall is best removed by means of the *Kerrison* chisel forceps, although under careful management an ordinary chisel may be used.

Neumann, and after him, *Ballin*, recommend that this stage of the operation be performed by making two parallel incisions, limiting the area to be removed in front and in rear. One incision is placed as far toward the anterior wall of the canal and the other as far toward the posterior wall as the area to be removed demands. These incisions extend about one-half inch outward toward the meatal orifice. A flap is made by

joining the two incisions externally by a third placed at right angles to the other two. The superficial tissue is removed with a periosteal elevator, bringing the osseous lateral wall into view, which is then removed by a chisel or a forceps, as described.

With the removal of the lateral aditus wall, the operative procedure is somewhat of a modified *Stacke*, performed without a post-auricular incision.

After-treatment: The operation completed, the wound is cleansed of blood, flushed with hot saline and antiseptic solutions. The external auditory canal is lightly packed with sterile iodoform gauze and the external ear covered with sterile dressings retained in position by a bandage. In many instances, the bandage and the outside dressing may be dispensed with, limiting ourselves to packing the meatus. Many remove the packing after a few days, and subsequently treat the affected ear with boracic acid insufflations. Our best results have been obtained from the insufflation of aristol, followed by a light packing of sterile gauze. The severity and the character of the discharge govern us in determining whether or not to wash the tympanic cavity with antiseptic solutions.

Exuberant granulations are to be guarded against; they demand the same treatment here as when they occur before the operation. In a period of time, varying from one week to many months, the discharge finally ceases, and the middle ear becomes clean and healthy.

Dangers of the Operation: When carefully and skillfully performed, the operation presents few dangers. Accidents are possible and should be guarded against. The tegmen, which is often very thin, may become fractured at the hands of the inexperienced; this may result in intracranial complications.

The facial nerve is sometimes injured. This results from pressure upon it either by instruments, or by the incus, and usually happens during removal of this ossicle. Either because dehiscences are present in the bony canal of the facial nerve, or because the canal is fractured during manipulation, the nerve may be injured. It is to be noted, however, that *Schwartze* reports that facial paralysis in these cases usually disappears within a period of from six to eight weeks.

When dehiscences are present, paralysis of the facial nerve may also result from pressure of blood clot behind the packing placed in the external auditory canal.

The dangers resulting from accidental dislocation, or removal, of the stapes are usually grave. Symptoms referable to labyrinthine involvement supervene, and if the intra-labyrinthine fluids become infected from the purulency of the middle ear, the possibility of meningeal invasion is a danger seriously to be apprehended.

The severance of the chorda tympani, as a rule, causes no serious results; a disturbance of taste on the affected side is the only evidence presented by this accident.

Injury to the jugular bulb is possible when force is used in cleansing the tympanic floor of granulations and detritus. The frequent presence of dehiscences here, especially in young subjects, must be kept in mind. When the tympanic floor is fractured, or the wall of the bulb injured, the possibility of a peribulbar abscess, or the formation of a thrombus with resultant pyæmia, is to be feared.

With care in instrumentation, when operating in regions whose anatomical relationships have proven them to be danger zones, these accidents are avoidable in the vast majority of cases. It is to be recommended that every step in the performance of ossiculectomy should be undertaken under full illumination, and, furthermore, that no force should be employed to extract the ossicles. Their separation from the structures in anatomical relationship to them must be made deliberately, and when loosened, they should be gently removed.

Value of Ossiculectomy: Opinions differ as to the value of the operation. *Heine* holds that isolated caries of the ossicles, even when associated with involvement of the aditus walls, often heals under expectant treatment. He admits that the extraction of the ossicles facilitates drainage, and that healing is therefore quicker; he cites cases where the caries involved the malleus, but avoided the lower tympanic cavity, and spared the conducting apparatus; in such cases he found the hearing almost normal. He therefore deprecates the necessity of opening the lower portion of the tympanic cavity to the purulent

exudate from the aditus, bringing as this does in its train pathological changes at the labyrinthine windows. In these cases, he considers ossiculectomy contraindicated. The operation, according to this view, is only of value in the presence of isolated caries of the ossicles.

On the other hand, many authorities find the value of the operation to lie in the fact that it not only provides better drainage for the diseased parts, but also in that it renders them more accessible to local treatment. On the whole, the prognosis as to results obtainable from ossiculectomy as a cure for a long-standing middle ear suppuration must, of necessity, be guarded. Its ease of performance, its painlessness, and its freedom from dangers renders it a procedure of value as a preliminary trial for a cure before the radical mastoid operation is urged.

As a means for obtaining improvement in hearing, personal experience has failed to demonstrate the desired results. Where all other means have been unsuccessfully tried, the removal of the ossicles and drum will occasionally bring relief from annoying tinnitus and improve hearing, by permitting the direct impact of the sound waves upon the labyrinthine windows.

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CHAPTER VI

THE SIMPLE MASTOID OPERATION

Historical—Surgical Anatomy of the Adult Mastoid Process—Surface Markings and Their Relation to Underlying Structures—Indications for the Simple Mastoid Operation—(General Symptoms, etc. The Subperiosteal Abscess—Its Location)—When to Operate—Contraindications—Preparation of the Patient—Anæsthetic—Instruments—Operation on the Adult—Blood-clot Dressing—Accidents—Faults of Technique—Anatomical and Surgical Landmarks on the Infant and Young Child—Operation on the Infant or Child—Faults of Technique—Study of Operative Findings—After-treatment—Significance of Post-operative Temperature—Wound Complications—Results of the Operation—Bone Regeneration.

Historical: The history of the simple mastoid operation is divisible into two chronological periods (*Whiting*). The first, extending from 1656 to 1864, is known as the experimental period, and the second, the era of the modern operation, extends from the latter date to the present time.

In the middle of the seventeenth century, we find *Johann Riolan* (1), 1649, proposing that the mastoid process be opened upon purely theoretical grounds, in cases of obstruction of the Eustachian tube, in an endeavor to equalize the atmospheric pressure on both sides of the membrana tympani. It furthermore appears that *Rolfinck*, 1656, suggested that the mastoid process might profitably be artificially opened. Both these writers considered the operation indicated for the relief of intractable deafness and tinnitus, with closure of the Eustachian tube; but there is no record to the effect that either of these pioneers ever put his opinion to a practical test.

The first to successfully open the mastoid cells for caries, was the French surgeon, *Petit* (2), 1674–1760. He seems clearly to

have appreciated the beneficial effects of the operation, and its possibilities as a life-saving procedure. In chronological order, we now find that *Heuermann* (3) successfully carried out the procedure upon a mastoid process which had spontaneously perforated, and *Morand* (4) successfully trepanned in a case of caries of the mastoid process, opening what is supposed to have been a subdural abscess.

Independently of these efforts, and without knowledge of them, a Prussian military surgeon, *Jasser* (5), successfully operated upon a soldier's mastoid, in 1776. His successor, *Fielitz* (6), was similarly successful, and the procedure was for a long time erroneously designated the *Jasser* operation. *Jasser's* reports aroused great interest, and the operation was looked upon as not only affording relief in cases presenting caries, but as a measure to relieve deaf-mutism. The operation failing to produce results, at the hands of *Löffler* (7), *Hagstrom* (8), and others, became discredited and fell into disuse.

The imperfect knowledge of the pathological anatomy of the ear produced a series of indications for the operation, which were largely a matter of guesswork, and brought in its train correspondingly unfavorable reports on its results. To these, the unmerited blow dealt the procedure by the death of *Baron Berger* (9), the personal physician of the king of Denmark, who submitted to the operation because of severe difficulty of hearing and intense tinnitus, and who died a victim of imperfect technique and injudicious after-treatment, caused prominent general surgeons, no less than authorities in otology, to decline to sanction the operation. Notwithstanding occasional favorable reports, and the endorsement of *v. Tröltsch* (10), whose work was based on scientific pathological research, the operation remained in disuse for the following decades.

The operation was again urged upon the profession by *M. Deziemeris* (11), who collected the published reports, and also employed the procedure, in the hopes of relieving deafness. Subsequent attempts to revive the operation by *Pagenstecher* (12), *Forget* (13), and others, received scant attention, and it was not until the works of *v. Tröltsch* (10), *Follin* (14), and *Lucke* (15) appeared that general interest was again aroused.

In 1873, *Schwartze* (16) proceeded to lay the basis of the indications upon rational anatomical grounds, but he was met by the prevailing adverse prejudice of *Langenbeck*, *Dieffenbach* (17), and others.

Because of the thoroughness and rationale of his work, and that of his assistant, *Eysell* (18), a gradual change in the almost universal estimate of the operation resulted, and the procedure again became generally sanctioned.

The credit belongs to *Schwartze* of finally establishing the operation firmly in otology, and it must be conceded to him that the various complicated modern mastoid operations are all based upon his fundamental simple opening of the mastoid process.

This interesting procedure, then, having dawned upon the surgical horizon of the seventeenth century as a brilliant application of professional ingenuity, after a brief period of fame, fell into undeserved disrepute, due to ill-advised extension of its indications; it acquired an undreamed-of importance in the latter half of the nineteenth century.

As *Whiting* (19) well says: "As a life-saving measure, few surgical procedures equal and none surpass in efficiency the modern mastoid operation."

Anatomical: The mastoid process derives its name from that portion of the temporal bone which articulates with the parietal bone at its parietal notch (parieto-mastoid suture), and with the occipital bone at the occipito-mastoid suture, where it abuts upon the squamous portion of the occipital bone.

The mastoid process borders upon the tympanic portion of the temporal bone at the tympanomastoid fissure, and upon the petrosa of the temporal bone. In the young, it is separated from the squamous part by the squamomastoid suture, which is usually obliterated in later life. The mastoid process is a broad, conical bony projection, pointing downwards, covering the greater part of the mastoid portion of the temporal bone. It presents a rough, markedly convex external surface, and an internal concave cerebral surface. (Fig. 15, A.)

Form: The external form and size of the mastoid process differs in individuals. In muscular adults, it is usually found

Fig. 11.—Vertical Section Through Left Temporal Bone in the Plane of the Axis of the Petrous Portion. (From Turnbull's Surgical Anatomy, with Permission.) The Mastoid Cells (red) are shown Radiating from the Antrum, mesiodorsad. The Lower Part of the Tympanic Cavity is Removed so as to Expose the External Auditory Canal. The Ossicles and the Stapes are Seen from Behind.

A.—Antrum.
B.—Incus.
C.—Superior Ligament of the Incus.
D.—Semicircular Canal.
E.—Facial Canal.
F.—Vestibule.
G.—Cochlea.
H.—Eustachian Tube.
I.—Tympanic Cavity.
J.—Internal Auditory Artery.
K.—Cartilage of Eustachian Tube.
L.—Levator Palati Muscle.
M.—Pharyngeal Orifice of Eustachian Tube.
N.—Superior Constrictor of the Pharynx.
O.—Stylohyoid Muscle.
P.—Styloid Process.
Q.—Digastric Muscle.
R.—Facial Nerve.
S.—Sternocleidomastoid Muscle.
T.—Anterior Cervical Muscle.
U.—Occipitomastoid Artery.
V.—Mastoid Cells.

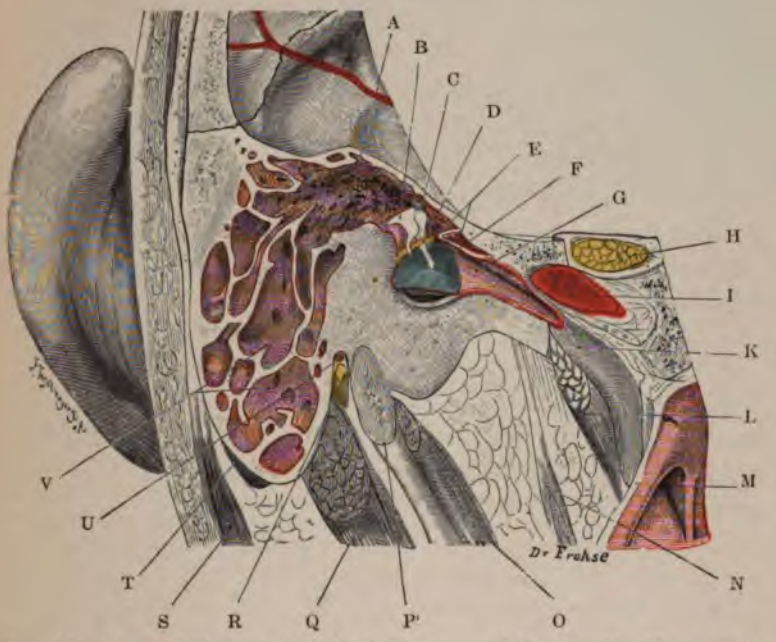

FIG. 14.—Vertical Section Through Left Temporal Bone in the Plane of the Axis of the Petrous Portion. (From Bardeleben's Applied Anatomy, with Permission.) The Mastoid Cells (red) are Shown Radiating from the antrum mastoideum. The Lower Part of the Tympanic Cavity is Removed so as to Expose the External Auditory Canal. The Ossicles and the Drum are Seen from Behind.

A—Antrum
B—Incus
C—Superior Ligament of the Malleus
D—Chorda Tympani
E—Tensor Tympani Muscle
F—Malleus Umbo
G—Eustachian Tube
H—Fifth Nerve
I—Internal Carotid Artery
K—Cartilage of Eustachian Tube
L—Levator Palati Muscle
M—Pharyngeal Orifice of Eustachian Tube
N—Superior Constrictor of the Pharynx
O—Stylo-hyoid Muscle
P—Styloid Process
Q—Digastric Muscle
R—Facial Nerve
S—Sterno-mastoid Muscle
T—Splenius Capitus Muscle
U—Stylo-mastoid Artery
V—Mastoid Cells

larger than in the non-muscular. We designate its external surface, the cortex, and its internal surface, the inner table. The cortex varies in thickness from .5 mm. to 10 mm., *Held* (20). The mastoid cells are situated between the cortex and the inner table.

The Mastoid Cells: These are hollow cavities lined with mucous membrane, radiating from the principal cell—the antrum mastoideum. With the exception of the antrum, which is fairly constant, the cells differ in form and in size. The mastoid antrum is a bean or kidney-shaped air space, whose concave wall is turned outward, and whose posterior lateral half is somewhat bent upon itself. Its length averages 12.7 mm., its breadth 6.7 mm., and its height 8.5 mm. (*Bezold, Schwartze* and *Eysell*) (18). The axis of the antrum lies in a somewhat curved line, continued from the Eustachian tube across the middle ear and through the aditus ad antrum. The anterior wall of the antrum is the posterior wall of the tympanic cavity. Internally, that is on its mesial wall, in its lower portion, the semicircular canal and the facial (Fallopian) canal form its boundary. The roof is the continuation of the tegmen tympani, and is known as the tegmen antri: the level of the antral floor is found at about one-half of the height of the posterior meatal wall. The axis of the long diameter of the antrum forms an angle of about 27 degrees with the posterior wall of the external auditory canal.

Held (20) places the average depth of the antrum from the skull surface, at about 12 to 15 mm.; this depth varies in individuals according to the age of the subject. It may be stated that the antrum is never deeper than the posterior wall of the external auditory canal. The mastoid cells are connected one with the other, and with the antrum, through which they communicate with the tympanic cavity by opening into the aditus ad antrum. (Fig. 14.)

In cross-section, we generally find that the mastoid cells become larger, the greater their distance from the mastoid antrum. Because of rarefaction or absorption of their demarcating walls, the typical cell arrangement is often lost, and the process shows, upon cross-section, an irregular arrangement of its cells. It is not unusual to find that the cells extend beyond the limits of

the temporal bone, on to the petrosal part of the occipital bone, besides spreading forward into the root of the zygomatic process. Occasionally well-developed cells are observed along the tegmen antri and tegmen tympani, while below, and often behind the sigmoid sinus, these cells attain unusually large dimensions. Cells have been observed spreading inwards toward the mesial line of the head and encroaching on the semicircular canals. The character of the cell arrangement between the cortex and the inner table varies. If the cells are large and numerous, the mastoid is designated pneumatic; otherwise, it is called a diploic mastoid. The tip may be either spongiosus, pneumatic or compact. *Zuckerkandl* (21) finds total pneumatization to equal about 37%; total diploic variety he estimates at 20%, and 43% of his observations were found to be of the mixed variety.

Age Changes: The mastoid cells are absent at birth, with the exception of the mastoid antrum which at that time is fully developed in size.

In the newborn the antrum lies very superficial, almost directly above and slightly behind the external auditory opening. During the first years of life, the antrum generally is somewhat egg-shaped, the other cells meanwhile gradually developing upward, outward, inward and downward, as age increases, until at the fifth year of life, they take on the adult type. Full development is usually reached only with the advent of puberty.

The Inner Table: The internal or the cerebral surface of the mastoid presents the fossa sigmoidea (sulcus sinus transversus) —a marked concavity, curving sharply at almost a right angle at the point designated "the knee," its general course twining upward and forward, and merging into the sulcus transversus occipitalis behind; forward and below, it terminates in the fossa jugularis. Generally speaking, the sigmoid fossa, containing the sigmoid sinus, pushes further forward on the right than on the left side, *Körner* (22) holding that the difference between the two sides equals 2.55 mm. The remainder of the inner table takes part in the formation of the cranial fossa; *Schultze* (23) finds that the cranial fossa lies higher on the right than on the left side.

Surface Markings on the Temporal Bone, and Their Relation to Underlying Structures: On the surface of the temporal bone are to be found certain landmarks which, because of their more or less constant relationship to underlying structures, are of great help in working out the surgical technique. These are the linea temporalis, the suprameatal spine of *Henle*, the "spongy spot," and the squamomastoid suture, or its remains. The linea temporalis is the continuation backward on the external surface of the temporal bone of a ridge—called the zygomatic ridge, or supramastoid ridge—which is the posterior termination of the zygomatic root. This ridge, or its lineal continuation, overhangs the external auditory meatus, and marks the upper field of safety for opening into the mastoid antrum. (See Fig. 15.)

The zygomatic ridge lies a little below the level of the floor of the cranial fossa. While this is a fairly constant relationship, in six specimens of 463 examined, *Held* (20) found the floor of the middle cranial fossa lower than the linea temporalis.

The position of the linea temporalis, and—in bones evidencing a sharp angle formed by the junction of the squamosa and the tympanic portions of the temporal—the suprameatal ridge are to be carefully located, as valuable surgical landmarks.

The suprameatal spine of *Henle* is a rather well-defined bony prominence or spica, situated at the upper posterior juncture of the tympanic plate and the mastoid portion of the temporal bone. It presents itself above and somewhat behind the posterior wall of the external auditory meatus, curving concentrically to the circumference of the external auditory canal wall. The spine is sometimes large, occasionally small, at times it projects prominently; often it is flattened, and in a certain number of cases it is entirely absent. *Yearsley* (24) found it absent in 8% of cases and very poorly marked in 12.57% of 2,000 specimens examined. *Broca* (26) cites *Kiesselback* as reporting it absent 18 times in 100 examinations, and *Schultze* fails to find it 11 times in 120 specimens. *Held* reports that in 463 examinations the spine was absent 12% of times, and that it was barely demonstrable 41 times. From these figures a fairly accurate estimate may be derived concerning the reliability of *Henle's* spine as a surgical landmark. When it is present, it has

a distinct value, and its relations to the floor of the middle cranial fossa, show the average distance between its upper margin and the level of the floor of the cranium to be about 6 mm. Occasionally, this distance is smaller, *Held* finding the floor on an equal level with the spine once, and *Randall* (25), examining 1,000 specimens in reference to this relationship, reports that the middle cranial floor was on the same level as the spine only 5 times. We are safe, therefore, in assuming that in the vast majority of cases, the cranial fossa will not be opened when the operative procedures are limited above by the level of the upper border of the spine.

The suprameatal fossa is situated immediately behind and sometimes slightly lower than the spine. It is a more reliable landmark in adults than the spine; it marks the external (lateral) boundary of the mastoid antrum. In the infant it is poorly defined and somewhat variable in position. It may be seen as an excavated depression, somewhat triangular or crescentic in shape, or it may appear as a mere slit. Generally, it presents as a collection of vascular foramina of varying size, and from this appearance has been designated the "spongy spot."

More constant than the spine, always noted by *Yearsley*, although *Held* failed to find it 36 times—it is a more reliable guide to the opening of the antrum than the spine. In children, this is not the case, as we shall presently see.

The squamomastoid suture is the remains of the squamomastoid sinus of infancy. It is observed as a line more or less clearly marked, having an irregular course, which extends upward from some point on the external surface of the mastoid tip, and runs toward the posterior margin of the external auditory canal. Its marking is irregular in the adult, and usually is demonstrable only by the adherence of periosteal fragments to it along its course, when the periosteum has been retracted to uncover it. Its value as a landmark is doubtful, except as a probable guide to the position of the sigmoid sinus. Since in the young the sinus develops from bone posterior to the squamomastoid suture, the blood-vessel is sought for behind the point occupied by the squamomastoid suture or its remains. It is not a reliable landmark, because by reason of some anomaly

.n its development, the blood-vessel may be found further forward than the suture would lead one to expect. In the infant and the young child, it possesses value as a landmark in determining the position of the blood-vessel.

The landmarks above described limit a field of operation located

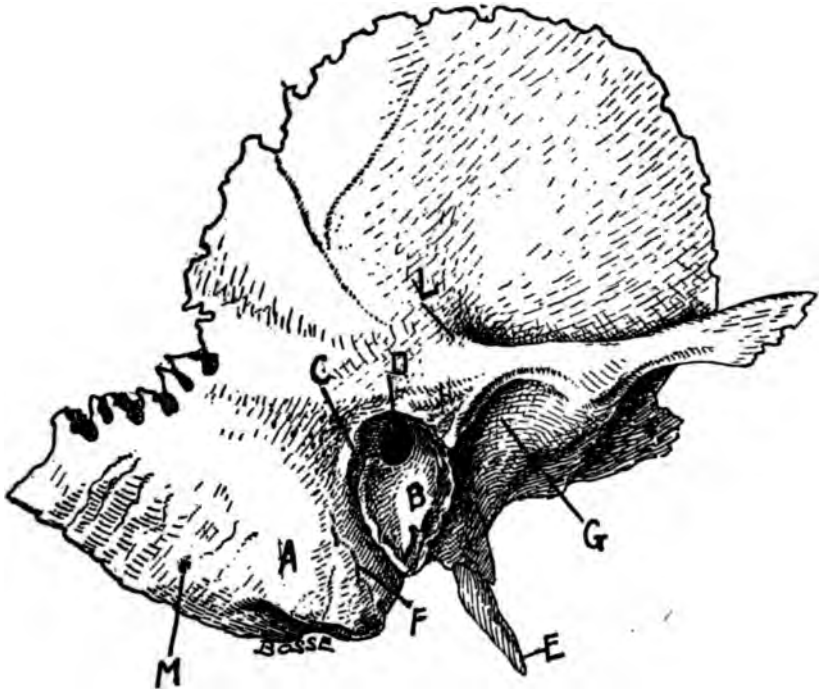

FIG. 15.—EXTERNAL SURFACE OF THE TEMPORAL BONE (ADULT), SHOWING LANDMARKS.

A, Mastoid Process. B, Tympanic Plate, External Osseous Canal. C, Henle's Spine. D, Canal lumen. E, Spyloid Process. F, Remains of Squamomastoid Suture. G, Glenoid Fossa. L, Root of Zygoma from which Linea Temporalis Continues Backward. M, Point of Emergence of Mastoid Emissary Vein.

within an irregular triangle formed by the linea temporalis, zygomatic ridge, or zygomatic root above; by the posterior meatal wall, from its upper junction with the mastoid portion of the temporal bone at the spine of *Henle*, downward toward the mastoid tip, in front; and by an imaginary line skirting the posterior margin of the mastoid tip and extending upwards and obliquely

backwards to meet the linea temporalis behind. If the squamo-mastoid suture is present, the third, or posterior line of the triangular field, will be made to coincide with it.

The field outlined above holds only for the beginning of the operative procedure, because once the antrum is located and opened, the removal of the cortex is continued until the evisceration of the mastoid cells has been accomplished to the necessary extent.

Indications for the Simple Mastoid Operation: Generally speaking, the simple mastoid operation is indicated when an acute middle ear suppuration or an exacerbation of a chronic middle ear suppuration has extended to and involved the mastoid cells, filling their cavities with purulent detritus, breaking down the cell walls, and eventually reaching the mastoid cortex producing periosteal inflammation and abscess formation; or where because of inherent hardness due to a thickened cortex, the purulent advance of the disease threatens by its further progress either to invade the internal ear or the cranial cavity or to involve the venous blood-vessels within the mastoid process.

In addition, *Schwartze* (27) has recommended the operation in cases where the mastoid is apparently healthy, where there is no evidence of pus retention, but where the mastoid process is the seat of pain of long duration and great severity, uncontrollable by any other means. These cases are designated "bone neuralgias."

To recognize the presence of these conditions, a brief review of the symptomatology of mastoiditis acuta is necessary. The patient presents definite general and local signs which must be accurately known and instantly recognized, lest the proper moment for operative interference be missed, and the patient's life be endangered.

General Symptoms: The patient suffers from retention of pus and from the absorption of toxins. Hence, we have at first, headache and malaise, with more or less of a rise in temperature. The rise of temperature is not a constant symptom in the adult, and even if present, is rarely above 101° to 102° F. In children, on the other hand, the temperature curve evidences a dis-

tinct rise, often to 103° F., and sometimes higher, especially toward evening. In Chart I we see a temperature curve rising to 104° the day before operation (child). When the drum remains imperforate in children, convulsions are often observed.

Averseness to exertion, profuse sweating, dizziness, nausea, and vomiting, accompanied by marked prostration, are evidences of a more advanced stage. In nursing infants, we observe a refusal to take their food; and they lose in weight. These symptoms are often accompanied by diarrhea.

As the pathological process develops, the patient presents a pallid, apprehensive countenance, the head is usually slightly tilted toward the opposite side, and held stiffly, and the neck muscles are perceptibly tense. The infant rolls its head on the pillow with a boring motion, and seems to rest best when held in the arms with the diseased region downward. In children, when unrelieved, facial paralysis is apt to supervene early. When the disease perforates the cortex and involves the periosteum, a swelling gradually develops behind the ear, which, upon palpation, is found to fluctuate. Oedema of the eyelids on the diseased side is frequently observed.

The pulse and respiration, in uncomplicated cases, are usually normal; in children, however, it is not uncommon, during the whole course of the disease, to note a pulse whose rapidity is out of all proportion to the temperature. Respiration usually remains unaffected.

The advent of, or the existence of, the ear discharge is to be noted and studied. The otorrhœa may be copious or slight in amount, or it may vary in quantity at different times. A copious discharge which suddenly disappears—as if arrested—or one which suddenly becomes less in amount and yet shows no abatement of the purulent process, is always to be looked upon with apprehension. A discharge which persists for a long time, especially when of fetid odor, in spite of antiseptic local treatment, even in the absence of other grave symptoms, invariably denotes mastoid involvement. This indicates operation. The bacterial examination of the discharge may help to throw some light upon the character of the invading organism, and thus help to decide whether or

not an immediate operation is indicated; this is the case if *Friedländer's* bacilli are found. In the presence of the severer streptococcic infections, it is safer to operate than to try palliative measures. Likewise, because of the extensive destruction which follows their invasion, the tubercle bacilli and the diphtheria bacilli demand prompt resort to antral drainage. In general, we may say, however, that the variety of the invading micro-organism, *per se*, plays no rôle as to indicating surgical measures. A dull, flat note obtained by percussion of the mastoid has been held by *Körner*, *Wilde* and *Eulenberg* to denote mastoiditis and to indicate operation (28). Mastoid involvement is usually demonstrable by the existence of pain, except in the tubercular or syphilitic types, or in the cases due to *Friedländer's* bacillus. The pain is generally steady, often intensified at night; among the aged and in diabetics it is not marked. Pain on pressure over the antrum, or over the mastoid tip, denotes involvement of these parts and, in conjunction with other signs, indicates operation. If present over the entire mastoid process, it usually means an extensive involvement. On the other hand, it should be remembered that large areas demonstrating pain may result from a periosteal inflammation over the mastoid cortex.

Generally pain is present in the early stages of all mastoiditis. Mastoid tenderness should, however, only be considered an indication for operation when other significant signs develop with it, or when the pain persists for a considerable time. Mastoid tenderness usually subsides after a few days. If it reappears, it indicates that the pathologic process has advanced. It is to be noted that pain can always be demonstrated upon pressure exerted just beneath the mastoid tip. This is demonstrable even in healthy mastoid processes, and such evidence must not be adduced as indicative of surgical intervention.

Misleading data are also presented when pain is the result of an otitis externa. In such a contingency, the hearing tests will show that the middle ear is normal, should the otoscopic diagnosis fail to clear up the mooted question. When both an otitis externa and an otitis media are present, the diagnosis is

extremely difficult; incision often is the only means to clarify the situation.

On the other hand, complicated cases often occur, where little or no evidence of pain is present, and which, nevertheless, show extensive destruction of the mastoid cells upon operation. These cases are frequently found among diabetics and alcoholics.

Given the presence of mastoiditis, the otoscopic picture will show, in the infant and in the child, an external auditory canal with a narrowed lumen caused by a periostitis of the underlying bone; in the adult, a sinking of the posterior superior quadrant, results from similar causes. These signs call for surgical intervention.

Extravasation of pus, which has found its way outward between the bone and the periosteal covering along the posterior meatal wall, has been observed by the writer in cases occurring among children, and is held to indicate early operation.

The membrana tympani is usually found red, swollen, and bulging, with a perforation in one or other of its quadrants. The pus coming away in pulsations denotes the pressure under which it is held. In children, because of the anatomical peculiarities of the temporal bone at this age, the drum is often imperforate, and its bulging extreme (29). Among adults, in a small percentage of cases, the drum will bulge markedly, showing a perforation that may be situated high—in *Shrapnell's* membrane—denoting an involvement of the aditus; such cases usually do not heal without operation.

Finally, where the mastoid cortex is involved, and is followed by the formation of a subperiosteal abscess, mastoiditis is usually fully developed and operation is indicated.

The Subperiosteal Abscess: The subperiosteal abscess is easily recognized upon inspection. The affected region appears swollen, red, with the ear standing off from the head at almost right angles. The head is held stiffly and tilted toward the opposite side. Closer inspection reveals the absence of the fold where the concha is attached; the skin in this region being spanned, tense and red. Fluctuation is often demonstrable. A fistulous opening from which thick, creamy pus exudes, may occasion-

ally be seen externally. The abscess may spread over the entire side of the head.

Location of Abscess: In adults, the abscess is usually found behind the ear; in children, it is either found above the concha, extending well over toward the zygomatic region, or at the mastoid tip, infiltrating the soft tissues in this region. Occasionally in younger children, the abscess overlies the squamomastoid suture.

In a certain number of cases, the abscess is located above and in front of the concha; sometimes we found that the middle ear cavity is not involved in such cases. Where the zygomatic region is involved, œdema of the eyelids on the affected side is commonly observed.

Subperiosteal abscesses covering the occipital bone have been observed in the region posterior to the mastoid process, leaving the process entirely free. In these cases, *Heine* believes that the pus emanates from the posterior cranial fossa, exuding through a bone perforation; in some of these cases the mastoid emissary vein has been held as the route traveled by the pus. Recently, I saw a case where the pus collected under the eye and extended to the cheek. At operation, a fistulous tract was traceable along the zygomatic process toward the eye.

When the abscess forms in the soft tissues of the neck, and the infiltration appears about the mastoid tip, the pus usually has penetrated the mastoid tip at the digastric fossa; this class of case has been designated *Bezold's* mastoiditis. The swelling is situated just below the tip, unless the infiltration spreads to infect the fascia of the neck. Marked fluctuation is not common in the *Bezold* type of mastoiditis. These abscesses develop where the mastoid process is involved and perforate the cortex, although *Heine* (30) has observed some cases where no opening through the bone was demonstrable. I have seen such abscesses, but never in children.

The perforation of the cortex in cases of subperiosteal abscess is usually located in the fossa mastoidea, ¼ to 1 cm. behind the posterior canal wall; occasionally the perforation is situated higher, sometimes lower. The opening is seldom seen upon either the lateral or upper meatal wall. In cases coming under

observation late, especially in children, large areas of cortex may be destroyed, and the opening be filled with granular detritus and pus. Recently, we operated upon an adult, aged 32 years, where the cortex was destroyed for a distance of 4 mm., and the fistulous tract extended to the uncovered sinus, and the whole area was filled with dark brown, ill-smelling granulations; no pus was present. *Urbantschitsch* (31) reports two cases where the abscesses perforated through the external auditory canal.

In the early stages of abscess development, pain, due to the stretching of the soft tissues, is present. In their later course pain is either not marked, or entirely absent.

Two types of subperiosteal abscess sometimes met with fail to show any connection with an involvement of the mastoid. In one type the aditus is the primary seat of the disease; here the abscess extends externally without involving the antrum or the other mastoid cells. In the second type, the abscess forms subsequent to inflammation of the glands which have broken down. Sometimes where glandular involvement is the primary cause of the abscess formation, a middle ear suppuration may coincidentally exist, and in such cases, a careful differential diagnosis is required, either to substantiate or exclude mastoid involvement. Reliance is placed mostly upon careful palpation, by which the outline of the mastoid process is recognized as distinct from the abscess swelling. When in doubt, it is advisable to incise the abscess and then palpate through the incision.

Finally, subperiosteal abscesses which occur along the external osseous meatal walls are to be differentiated from otitis externa. Such are usually concomitant with an acute exacerbation of a chronic middle ear suppuration. Usually painless, sudden in development, failing to evince tenderness when the concha is moved, or when pressure is exerted over the tragus, their character soon becomes evident. Since the existence of subperiosteal abscess usually denotes a purulent mastoid involvement, the presence of this lesion indicates immediate operation.

Upon summarizing the conditions which call for the performance of the simple mastoid operation, we find the operation indicated in:

(1). Long-standing acute middle ear suppurations which resist local, rational treatment; or acute middle ear suppurations where symptoms of pus retention and toxic absorption supervene.

(2). Cases of acute mastoiditis, characterized by pain, which becomes intensified on pressure over the antrum, the tip, the mastoid emissary vein, or the posterior osseous meatal wall; by fever which is persistent (especially in children) after paracentesis; and by a sinking of the posterior superior meatal wall, or a narrowing of the lumen of the external auditory canal.

(3). Cases of acute middle ear suppuration, with nausea, vomiting, dizziness, or facial paralysis; or with symptoms of intralabyrinthine or intracranial involvement supervening.

(4). Cases of subperiosteal abscess.

(5). Cases of persistent, unbearable neuralgic pains of the tissues of the mastoid region.

When to Operate: Given the symptom complex characterized by the above indications, when shall the operation be undertaken?

In the usual, typical uncomplicated cases, the best results are obtained if the operation is performed just after the first or hyperæmic stage of mastoid inflammation has passed. This time is generally reached 24 to 36 hours after the advent of mastoiditis. We prefer to wait for this period, as nature will, by that time, have shut off the smaller venous blood-vessels in the mastoid, and thus lessen the probability of invasion of the sinus. Lack of attention to this detail perhaps, is the reason that so many sinus thromboses occur in the practice of some, while they are rare in the practice of other surgeons whose experience is equally extensive. Furthermore, the body resistance is better 24 hours after infection, and better results are obtainable from the operation; finally, it affords time to observe the case, to examine the character of the otorrhœa, and to attempt abortive measures.

At the first sign of intralabyrinthine involvement—nausea, dizziness, nystagmus, facial paralysis—the operation should at once be undertaken. The first suspicious symptom of intracranial or sinus complication, likewise, demands immediate surgical relief.

With the exception of infants and young children, we may postpone operative measures with safety longer in the young than in the aged; in the latter osteosclerotic changes are more apt to be found than in younger individuals; the thicker and the harder that the osseous walls enclosing a purulent middle ear are, the greater the danger of the pus spreading in other directions. In considering mastoiditis, a dangerous disease in persons over forty years of age, I subscribe to *Heine's* opinion; furthermore, when an acute middle ear suppuration in patients of this age does not subside in from 4 to 6 weeks, it is far better to perform mastoidectomy than to continue palliative measures.

The length of time that a persistent acute purulent otorrhœa may be safely watched in young individuals varies; such cases demand close supervision and the operation should be performed at the first disquieting symptom. The acute process may last for months.

There are cases where the process in the middle ear has subsided, but where the mastoid involvement progresses. Such cases are more often observed than is supposed, and the operation is indicated as soon as the condition of the mastoid is recognized. Recently I saw two such cases, one in an adult (an alcoholic), where the mastoid condition was unrecognized until a subperiosteal abscess had developed, and the second, in a child; both cases presented normal middle ears.

Finally, it is well to operate at once when an acute exacerbation supervenes upon a chronic middle ear suppuration. The chronic pathological processes bring in their train eburnization of the bone, and create a hard, bony wall which, like osteosclerotic changes due to age, tend to increase the possibility of complicating lesions. The soil furnished by an underlying chronic process offers culture media for the rapid development of acute disease, and unless promptly relieved this may lead to dangerous sequelæ.

Contraindications to Mastoidectomy: Advanced tuberculosis, the later stages of diabetic cachexia, and the existence of hemophilia in a patient are contraindications to the operation. Moderate pulmonary tuberculosis is not to be considered a contraindication. Many tuberculous patients, who would not have

survived the mastoid attack, have been successfully operated upon. This is also the case in diabetic cases. The mortality in the latter is considerably greater than in tuberculosis cases. The rules of general surgery apply to hemophiles.

Preparation of the Patient: The preparation of the patient for mastoid operation should begin twenty-four hours before the time scheduled for the operation. The external ear, paracentesis having already been performed, is thoroughly cleansed and filled with a wick of gauze to act as a drain.

The hair is shaved from the head for about three inches around the ear. In women, the longer hair from the top of the head is separated from that on the affected side and firmly braided and pinned up. To prevent the straying of short hair onto the operative field, a one-half inch strip of gauze is put on the head at the boundary of the hair. This is pasted into place with collodion. The exposed surface is then thoroughly scrubbed with an alcoholic soap solution and an antiseptic solution (lysol or bichloride of mercury) and a wet green soap dressing applied. The patient is placed in bed, a purgative administered, and a fluid diet ordered.

If operation is urgently demanded then the local preparation is made just before operation, and the bowels are emptied by the administration of a copious enema.

When the instruments and all the accessories are ready, the room for operation in order, and a good headlight for the illumination of the deeper wound recesses at hand, the patient is placed upon the table with his head resting upon a block carved out to fit the head.

A rubber cap is placed over the head to restrain the hair; the head is turned toward the opposite side, and the neck on the diseased side slightly put on the stretch.

The preliminary bandage is now removed, and the parts are again thoroughly cleansed with antiseptic soap and ether; sterile towels and sheets are placed over the neck so as to leave only the operative field exposed.

Anæsthetic: Usually a general anæsthetic is necessary. Ether is usually employed, but in young children, in pronounced alcoholics, or in those whose respiratory tract is liable to disease or

already is affected, chloroform is preferable. Cocaine anæsthesia has successfully been employed in simple mastoidectomy. Whether nitrous oxide is employed preliminary to the administration of the ether, or whether some of the other refinements of the art of administering general anæsthesia are used, depends largely on the anæsthetist. We believe that expert anæsthetists should be employed wherever possible to lessen the danger of ether pneumonias, and to assure absolute safety to the patient.

Strict aseptic precautions should govern the preparation of the surgeon, and the handling of the instruments. The hands should be scrubbed to the fullest extent, and then dressed in sterile, soft, thin rubber gloves. It is almost impossible to sterilize the hands, while the gloves can be rendered sterile by dry or wet sterilization, and then be immersed in a bichloride of mercury solution (1:500) after being put on; they are then rinsed in sterile water. Thus we minimize the dangers of infecting the wound from any external agency. Although the cavity opened into the bone is the seat of a purulent infection, in the performance of operative procedures, where the chances of exposing the dura or the sinus are ever present, the introduction of bacteria other than those already in the region, and which may have established for themselves some degree of tolerance, may complicate the case by a secondary infection. This additional infection may be of sufficient severity to turn the scale against the patient's recovery.

The Instruments: The market is full of a variety of instruments; efforts should be made to become dexterous with one set, and new instruments should be added only when they represent distinct advantages over the old and well-tried ones. The personal equation counts largely here, and while there are gifted individuals, in whose hands almost any instrument will be safely and cleverly employed, better safer and quicker work is obtained if the surgeon is well acquainted with his instruments.

The set of instruments should embrace all that is necessary, not only to perform the operation indicated, but also to meet any possible emergency which might reasonably be expected to happen in the course of the operation.

Briefly stated, we require a few well-sharpened scalpels, about a dozen artery clamps, a hoe-shaped periosteotome (*Langenbeck's*), a curved and a straight pair of scissors, hand retractors, two self-retaining retractors (*Allport-Jansen* model); a set of chisels or gouges (*Lucae's* flat chisels with rounded cutting edge are the best, or *Whiting's* hollow gouges), a metal or wooden mallet; thumb forceps (bayonet-shaped, three in number, and three of the mouse-toothed variety); probes; rongeurs of various sizes; curettes (either *Lucae* spoon type, or *Richard's* curettes—the latter preferred); needles, needle holder, etc., etc.

This makes a good working outfit, to which, when the operation is undertaken outside of a hospital, an infusion apparatus and hypodermatic syringes should be added.

The Operation on the Adult: The procedure has for its object not only the exenteration of the mastoid cells, but also the establishment of post-auricular drainage of the mastoid antrum, so that paracentesis having been performed, a counter opening is made the better to drain the middle ear.

To accomplish this result most dexterously, and to avoid adventitiously opening the cranial cavity, or the venous circulation, a technique has been developed which, although differing slightly in the hands of various surgeons, in the main is followed by all.

The patient is anæsthetized and prepared, and the concha is turned forward upon itself.

Where a periosteal, retro-auricular abscess is present, it is best to make a small incision first and permit the escape of the pus. The parts are then again thoroughly cleansed, and the operation proper is begun.

By thus first eliminating the accumulated pus of the abscess and then making the full integumentary incision, we prevent washing of the freshly cut surfaces by the pus escaping from the abscess.

The Incision: The incision is made parallel to the auricular attachment, from its upper to its lower pole, and extended downward as far as is necessary to fully expose the mastoid tip. The incision is about ½ cm. distant from the auricular attachment throughout its entire length.

Whiting (19) meets this incision by a second one at right angles to it, so as to form two triangular skin flaps. We do not hold this to be necessary, unless the exigencies of the operation later demand it. We usually find that sufficient exposure of the mastoid cortex is obtained by the primary incision, and only make the second when later we find that the first is insufficient to accomplish our purpose.

In making the incision, the cut should not be carried forward at its upper extremity unless the necessity of later removing the zygomatic cells demands it; severance of the fibers of the temporal muscle which occurs when the incision is thus carried forward, results in a falling or drooping of the auricle.

The knife must be held with its blade at right angles to the skin, and in making the incision, the knife should penetrate at one sweep down to the bone, through all the soft tissues.

Profusely bleeding blood-vessels are quickly caught and the clamps are left in position until the end of the operation; ligature is very rarely required.

The periosteum is rapidly pushed backward and forward from the two lips of the wound, exposing the underlying bone as far as the skin incision permits. This is best accomplished by means of a hoe-shaped periosteotome. The periosteum should be pushed forward so that the posterior meatal wall comes into view, and backward until the posterior limits of the mastoid are uncovered. In pushing backward, care is exercised not to tear the mastoid emissary vein, as the bleeding which results obscures the operative field. If this blood-vessel is situated far forward, and is cut or is inadvertently torn, a small plug of iodoform gauze dipped in absolute alcohol is pressed firmly into its point of emergence from the skull, to check hemorrhage at this point.

After the retraction of the periosteum, shreds of this tissue will be found adherent to the site of the obliterated squamo-mastoid suture; the periosteum is also found rather firmly attached and in immediate connection with the muscular fibers of the sterno-cleidomastoid muscle at the mastoid tip. These attachments are severed with the curved scissors.

During these procedures, considerable oozing from the skin-wound takes place. The blood is wiped away, and a self-retain-

ing retractor placed into position. This retractor not only holds the edges of the wound widely apart, but by the tension which it exerts on the wound-lips checks the hemorrhagic oozing.

A careful examination of the exposed bony surface is now made to note diseased areas, to locate fistulous openings, and to recognize the important landmarks. This examination also furnishes data from which the surgeon estimates the character and conformation of the mastoid with which he is dealing. The extent and the depth of fistulous tracts are explored by a rather thick, blunt probe; a probe of this character is less liable to injure exposed dura or sinus wall.

To estimate the character of the mastoid under operation, we note its shape, its contour, and its surface markings, and the angle which the posterior osseous meatal wall makes with the outer surface of the mastoid cortex. From the angle referred to, we learn the direction toward which to chisel to reach the antrum, and also to estimate the probable location of the sigmoid sinus.

According to *Körner* (32), the floor of the middle cranial fossa and the fossa sigmoidea are nearer the external auditory canal, the tympanic cavity, and the mastoid antrum in brachycephalic skulls than in dolichocephalic heads. The cranial fossa is usually lower on the left than on the right side; and *Trautman* (33) considered it noteworthy that the more strongly the sinus sprang forward, the greater was the demonstrable angle formed by the juncture of the meatal wall with the mastoid cortex.

The landmarks have already been described, and they limit the operative field in the early stages of the procedure. In cases where fistulous tracts are presented, they are cleaned out with the spoon curette, and from these points the evisceration of the mastoid cells proceeds. If the cortex is found intact, our field is bounded by the linea temporalis above; in those rare cases where it is absent it is limited by the continuation backward of the upper border of the zygomatic root. Toward the front, the anterior boundary is presented by the posterior osseous meatal wall, or the os tympanicum. In well-marked specimens, this ridge and the process mastoidea, where they have grown together,

form somewhat of a ridge. The ridge is kept in view in the early stage of the subsequent steps, and where it is absent, an artificial demarcating line is made with the chisel.

From now on, the technique changes in the hands of different surgeons. *Heine* (30) and the European surgeons generally remove the cortex, piece by piece, until the antrum is uncovered. *Whiting* (19) constructs an initial groove along the cortex with a medium-sized gouge, placing the groove along the extreme anterior border of the mastoid process, skirting the brim of the osseous meatus. This is only of sufficient depth to expose the underlying structures. Successive grooves are then constructed paralleling the initial groove, until the cortex is removed. Recently, a method of opening the cortex has been advocated which presents some distinct advantages over other methods. This consists in opening the mastoid process first at the tip. The tip is freed and is removed with rongeur or chisel as the primary step of the bone surgery. By working in this manner, the sigmoid sinus is usually easily located, and its injury avoided, even when the blood vessel is far forward. We have tried the operation in this way and up to now have seen no disadvantage in operating in this manner.

Generally, we prefer to attempt to enter the antrum as the first step in the operation, and to keep the cortex with its known landmarks intact as long as possible. By creating a large superficial opening, gradually deepened, we have often seen difficulty experienced in correctly locating the antrum after the surface landmarks have been removed and their relationship lost. For experienced operators, who know the surgical landmarks thoroughly, the plan to open at the tip first may be an easy route toward the antrum, but for those less expert, and for beginners, the direct route to the antrum as the first step in the operation is recommended.

Macewen reaches the antrum mastoideum through a triangle placed on the cortex overlying it, and designated by him the supra-meatal triangle. It is formed anteriorly by a base line dropped from the posterior root of the zygoma, and coinciding with the posterior border of the external auditory meatus. Above, the triangle is bounded by the posterior root of the

zygoma. Below and behind, these two sides of the triangle are connected by a line running on part of the descending plate of the squama which forms the arch of the osseous part of the external auditory canal. At the upper base angle of this triangular area, there is usually a depression evident. This roughly corresponds to the "spongy spot."

Placing a chisel of medium width at the "spongy spot," or just behind and slightly above the spine, a small area of cortex is removed. With a gouge or spoon curette, we penetrate inward, following, as we advance into the interior, paralleling the direction held by the posterior meatal wall; thus the antrum is soon uncapped.

If the external contour suggests irregularities in development, it is safer to remove the mastoid cortex for some extent, keeping the line of the posterior meatal wall and the upper boundary of the operative field in constant view.

As we penetrate into the deeper parts we must proceed with the greatest possible caution lest the sinus or the dura be injured or the antrum entirely missed. The antrum is usually found at a depth of between 13 to 15 mm., differing in individuals according to the age and the character of the mastoid under operation. *Politzer* (34) gives the safety limit as being at a depth of 5 to 6 mm., while *Kerrison's* (35) observations place the average depth at 10.9 mm.

In making the primary attempt to uncap the antrum, if the use of the probe fails to demonstrate the accomplishment of this endeavor after a depth of about 10 mm. has been reached, we deem it safer to desist from further attempts. We then proceed to enlarge our cortical opening, and approach the depths of the wound gradually, eviscerating the mastoid cells as we go, until we gradually reach the level of the antrum and then open it. The advantages of this latter procedure is that the surgeon sees where he is going and just what he is doing, and is less likely to miss the antrum. With reasonable care, however, in following the direction of the posterior meatal wall, and in keeping close to it as we advance, the mastoid antrum will usually easily be opened. We demonstrate the opening of the antrum by introducing into it a probe whose tip is bent at a right angle. When

the tip of the probe is pushed into the opened cell, the bent part is generally insinuated forward under the meatal wall, pointing toward the membrana tympani. If upon attempting the withdrawal of the probe, the bent portion is found to impinge upon the mesial extremity of the meatal wall, then we know that its tip lies in the aditus; this confirms the fact that the antrum has successfully been opened. Additional data in this regard are presented by the depth at which the probe rests. Occasionally air bubbles in the blood are evidence that the antrum is uncapped. A general examination of the walls and the roof of the antrum is then made with the probe which has been introduced.

The mastoid cortex is now removed, in a manner somewhat similar to that advocated by *Whiting*. From the opening already made which leads to the antrum, we make a groove downward toward the tip, hugging closely the posterior meatal wall, but leaving a slight thickness of cortex standing to hold our outline.

The groove is rapidly deepened either with a spoon curette, or the *Richards'* curette. As the tip cell is uncovered, we begin to work backward toward the posterior limits of the mastoid tip, retaining the shell of the lower end of the mastoid tip unbroken as long as possible. With a rongeur, we work backwards, removing the remainder of the mastoid cortex, working toward the region of the sigmoid sinus. The cells are removed, and the cavity deepened to the inner table.

Opening the tip cell early, and working backward and upward from it, aids considerably in properly locating not only the sigmoid sinus, but also the "posterior tip cells," and the cells located behind and below the sinus, which otherwise are easily overlooked. At the tip, the inner table is very superficial, and once positively identified is easily followed upward and over the sinus, eviscerating the cellular elements by means of rongeur or curette.

As we go upward from the tip, we come on the convexity of the inner table when it overlies the sinus, and continuing over this, working toward the tegmen, we gradually, but progressively, remove the mastoid cells until the upper boundary of our operative field is reached. Above the sinus, that is, between the

sinus knee and the tegmen, the cells spread backward to a variable degree. These are followed and removed.

The general rule in removing the mastoid cells, is religiously to follow every cell lead uncovered to the inner table.

Irregularities of bone are smoothed, and the cells just below the tegmen cleaned away, until the bony floor of the cranial fossa is in view.

The cells are now followed to the zygomatic region, and as much of the zygomatic root as is of cellular character is removed. These cells often reach a considerable distance toward the face, and demand complete eradication.

The bottom of our bone cavity now receives final attention. The cavity generally needs deepening along the posterior meatal wall. The cells here are usually small, and as they are cleared away at the upper portion of the region lying near the meatal wall, the hard, shining, smooth outline of the horizontal semicircular canal which forms the internal (mesial) and the lower border of the antrum comes into view.

The antrum is carefully cleaned of all granulations and pus, care being exercised during the procedure not to dislocate the ossicular chain. The bone surgery is completed by slightly lowering the height of the posterior meatal wall.

We now have a bone cavity which extends from the tegmen above, to the inner table of the tip cell below, and from the posterior side of the posterior meatal wall in front to the posterior limits of cell formation behind; this forms a large, irregular, triangular-shaped cavity. At the bottom of the upper anterior corner of this cavity we note a small, hard, white protuberance—the horizontal semicircular canal. In the back of the excavation, the protuberance of the inner table which covers the sigmoid sinus, forms a gentle bulging, while above and in front, the irregularity of bone outline denotes the place where the zygomatic cells have been removed. (See Fig. 16.)

The steps just described give the usual procedure. It must be remembered however, that the steps in the operation are governed largely by the conditions present; the essentials however, are the same in every case.

Where the purulent process has penetrated through the mas-

FIG. 16.—THE COMPLETED OPERATION ON THE BONE (ADULT) SHOWING:

A, Root of the Zygoma. B, External Auditory Canal (floor). C, Canal Lumen. D, Opening into Antrum Mastoideum. E, Inner Table Overlying Sinus. F, Ridge of Bone Left Standing to Form the Posterior Wall of the External Auditory Canal.

PLATE VI

toid tip into the underlying muscular tissue, e.g., where it has formed a *Bezold's* mastoiditis, then the entire tip should be removed. Occasionally lengthening of the lower end of the skin wound is necessary to afford better drainage for the soft tissues of the neck. At times no external evidence of purulency in the muscles is evident; upon exerting pressure upon the soft parts, however, pus will ooze into the mastoid wound. Such cases of diffuse purulent infection of the soft parts are grave because of the extreme difficulty of evacuating the pus.

Often the floor of the middle cranial fossa lies high, and the cells must be followed upward for a considerable distance before the tegmen is uncovered. I operated upon a case in which the cells extended 9 mm. above the roof of the external auditory canal, equaling in distance that existing between the external auditory canal roof and the mastoid tip. To properly eviscerate the cells in this case, the temporal muscle was incised and retracted.

In sclerotic mastoid processes, or in cases where the mastoid cortex is exceedingly thick as the result of extensive eburnization, the above procedures cannot be undertaken. In such cases, the chisel offers the best means to open the antrum and exenterate the mastoid process. The proper management of the chisel is difficult. The instrument should be lightly held between the thumb and four fingers, not as a carpenter employs this tool, but rather as it is held by the sculptor (*Heine*). The instrument must "feather" at each stroke, returning to its original position after each hammer blow. It must not be placed at right angles to the cortex, but rather at a very acute angle, so that shallow, broad chips are removed at each stroke. At the commencement of the operation, the chisel must never be directed backward or upward; it should point toward the direction of the external auditory cana wall. The use of the chisel should be restricted as far as conditions will permit. *Grossman* (36), *Held* (37), and others claim that it causes cerebral shock and produces psychic disorders; *Heine* believes that the shattering force of the blows of the hammer upon the chisel are factors which tend toward the extension of circumscribed meningitis, and also that this force may cause the rupture of brain abscesses.

The complications resulting from inadvertent exposure of the dura or the sinus will be considered in subsequent chapters.

When the evisceration of bone has been completed, the external auditory canal is again thoroughly cleansed, and the entire cavity washed with hydrogen peroxide followed by a (1:2000) solution of bichloride of mercury. Some surgeons content themselves with dry wiping of the cavity. Recently the writer has adopted iodine in 10% aqueous solution as a wash for the bone cavity. It has given excellent results.

Careful search is made along the edges of the wound to remove splinters, and the cavity is now ready for its first dressing.

One of two procedures is now followed: The wound may be lightly packed with a strip of iodoform gauze, a strip of plain gauze placed as a counter drain in the external auditory canal, and the external dressings applied, or the cavity of the wound is permitted to fill with blood, the skin sutured, and primary healing attempted by means of the blood-clot treatment.

In the open method of treating the wound, it is of the utmost importance that the gauze packing be lightly applied. Often in our earlier experience we were at a loss to account for the slowness with which granulations made their appearance, until we found that it was the tightly packed wound that was at the bottom of the trouble. The looser the packing, consistent with the surgical requirements of the given case, the speedier the granulations appear. Iodoform gauze can usually be dispensed with after the first dressing. The subsequent treatment of the case will be described below.

In cases where a large excavation has been made necessary by an extensive development of the zygomatic cells, we usually place one or two sutures in the skin. The sutures are passed deeply, taking in all the subcutaneous tissues. This aids in preventing a subsequent drooping of the ear and gives better final cosmetic results.

Blood Clot Dressing: Where the blood clot after-treatment is desired, the cavity is permitted to fill with blood. Roughly wiping the wound edges usually accomplishes this. The periosteum is pushed into place over the cavity, and it and the skin lips of the superficial wound are sutured together. In lieu of

sutures metal suture clamps may be employed to hold the wound edges together. The lower end of the wound is often left slightly open, and a small strip of gauze introduced to act as a drain, or a cigarette drain is placed in position. The external auditory canal is lightly tamponed, and external dressings applied; these are removed daily and the wound inspected, so that at the first untoward sign it may be reopened.

Unfortunately as yet we are not ready to determine the relative value of these two methods of procedure. For the blood clot, it is claimed that the patient is spared the frequent, annoying changes of dressings, and the entire post-operative period is surprisingly shortened. Furthermore, the cosmetic results are much better than those obtained by the open method. On the other hand, in middle ear suppuration, where the mastoid has become involved, and there is present a virulent suppuration in the tympanic cavity, the aditus, and the antrum, it seems to me that the closure of the post-auricle wound and the organization of the blood clot, within a short time (usually at the end of the first week) defeats one of the purposes of the operation, by preventing drainage for the middle ear from behind during its subsequent suppuration. The blood-clot treatment precludes making a counter opening. The pool of blood within the excavation may have inherent in itself, bactericidal properties; but it would appear more likely that this clot of blood will receive an inoculation of bacteria from the exudate coming from the tympanic cavity and the aditus, and if the pathologic process is at all virulent, the clot will probably become infected and disorganized. This is exactly what has happened in the majority of the cases where we have employed the blood-clot method.

Good results have been, however, reported by competent observers. *Sprague* (44) operated upon 186 cases, using the blood-clot method 129 times. He reports that 60 cases healed in from 12 to 28 days, the majority in from 18 to 21 days. In 69 cases, the typical blood-clot method was used, and in 42 of them, healing resulted without interruption in from 7 to 15 days.

In the majority of my cases it has failed for the reasons above

stated. Some brilliant results were, however, achieved. At the present time, I can only say that for me, the subject is still *sub judice*.

The writer does not advocate the employment of the blood clot in cases in which the sinus or the dura has been exposed, or where an erosion or a defect due to disease was noted in the wall of the horizontal semicircular canal. Where the blood clot has been employed and the post-operative temperature either remains high or rises higher than before operation and does not recede at the end of the second day; or when upon inspection of the wound on the day following the operation, the aural discharge is fetid, or the post-auricular wound either does not unite or show signs of local infection, then the post-auricular wound should be reopened, the contents of the cavity removed, the cavity washed with antiseptic solutions, and the patient should subsequently be treated by the open method.

Accidents During Operation: The most common accident during the operation is the unnecessary exposure of either the dura or the sinus. When the dura is inadvertently exposed and remains uninjured, the opening should be enlarged, so as to expose a considerable portion of the dura. This devise provides drainage and prevents local inflammation. When the exposed dura is healthy, it is of a blue-gray color; if diseased, it will be found discolored and hard to differentiate from its surroundings. The general rule in exposure of unhealthy dura, is to continue to expose it until healthy dura is reached, if this is possible. If the dura is accidentally torn, free bleeding takes place. The site should be carefully cleansed with alcohol, and an iodoform plug dipped in alcohol placed over it. The operation is then continued; the same general mode of procedure is carried out as when the sinus is uncovered. If its wall is discolored, we expose it until hea thy appearing sinus wall comes into view. When healthy sinus is accidentally opened free hemorrhage results. At first a large tampon is placed over the bleeding point to control the hemorrhage; in a few minutes this is replaced by a small iodoform tampon moistened with alcohol. This small tampon is placed directly over the opened area. When this accident happens early in the operative procedure, the plug is pressed

between the sinus wall and the bony encasement, and the operation is then continued.

It is of the greatest importance in the exposure of both sinus and dura that all bone splinters are removed between the dura and the tegmen and between the bony covering and the soft sinus wall. When no attention is paid to this detail, such splinters act as local irritants and may be the cause of inflammatory reaction.*

When the purulent tract follows the direction of the sinus, great care is to be exercised when curetting in the region where the facial nerve crosses the sinus; its accidental injury is possible at this point. The facial nerve is also liable to accidental injury during the curettement of the rear of the posterior meatal wall. This accident is often avoidable if care is taken not to undermine this wall. A minute knowledge of the anatomy of the facial nerve is requisite in mastoid surgery.

Faults of Technique: At the commencement of the operative procedure, usually in the hands of the inexperienced, the edge of the knife is not held perpendicular to the bone. Consequently the incision is slanting and results in poor cosmetic effects.

If the primary incision does not penetrate to the bone at one stroke, the chances of fragmentary tears of the periosteum are increased. The preservation of as much of the periosteum as possible is desirable; tearing or shredding the periosteum is a technical error, as the growth of new bone proceeds from the periosteum. I had occasion to re-operate upon three cases—one a year, and the other twenty months, and a third within six months, after the primary operation—in which I found new bony deposits along the entire lower portion of the mastoid excavation. The new bone was loosely put together, and I have no doubt but that in time it would have become harder and denser, had not a secondary infection necessitated the radical operation.

The slipping of the knife or periosteal retractor, with resultant injury to the cartilage of the concha, may bring in its train an

* We shall consider both dura and sinus complications under separate chapters. Here we wish simply to direct attention to accidents that occur to these structures during the course of the simple mastoid operation.

infection of this structure, and from the resultant enchondritis ugly deformities may develop.

With the exercise of reasonable care and with sufficient practice, such faults of technique are avoidable.

In pushing the periosteum forward, firm, steady pressure is to be exerted and care exercised not to tear the membranous auditory canal from its bony attachments. This canal may safely be separated for a short distance from its underlying osseous parts, in order to give the surgeon an idea of the direction in which the osseous canal runs; the tearing of the canal from its attachment, however, usually brings an atresia of the external auditory canal in its train. If the canal is thus separated, proper tamponade should be begun at once to overcome the threatened atresia.

In starting the initial opening—at the site of election for entering the mastoid antrum—a common fault of technique is made when the opening is placed too low, and the antrum thus missed. *Whiting* correctly says, "the error most commonly committed in the search for the antrum is the practice of seeking it too far below the temporal ridge." Furthermore, even when the point of election is correctly located, and the surgeon does not hug the meatal wall during the advance into the interior of the bone while making the opening into the antrum, that is, if he does not make his opening in a direction parallel to that taken by the external auditory canal, then the objective of his procedure will invariably be missed.

If the antrum is missed, after the cortex has been widely opened, a search for it will eventually reveal its position, higher than suspected, usually just beneath the floor of the cranial fossa.

It is a technical error to persist in the use of the chisel longer than necessity demands; upon the evil results of prolonged use of this instrument we have already commented.

In removing the mastoid cortex, reference was made to the fibrous attachment of the neck muscles whose insertions are found about the mastoid tip. Such attachments should be cleanly cut with the scissors. It is technically incorrect to tear through such attachments. Furthermore, when employing the

curette in the region of the tip the sharp edges of this instrument should be brought as seldom as possible into forcible contact with the soft parts, lest their injury and their subsequent infection produce cellulitis of the neck.

The accidental exposure of dura and sinus, while not actually faults of technique, are usually avoidable if the operator proceeds cautiously. The injury of these structures is usually due to faulty use of the rongeur or the curette. Accidental opening of the sinus or injury to the dura by tearing, is often absolutely unavoidable. In regard to the sinus, the uncertainty of its position is a great factor in causing this accident.

We have observed a surgeon who in exposing a sinus, at every bite of the rongeur nipped its wall. Such practice is reprehensible, as the speed obtained is not commensurate with the results desired; such an injury to the blood-vessel may result in serious complications. Finally, it often happens that repair is delayed because all cell walls are not removed, and the entire bone cavity is left roughened rather than smoothed. We do not hold it necessary to polish the bone surface, but on the other hand, hold it an error to leave bony irregularities. In conclusion, it hardly is necessary to add that all diseased tissue demands entire removal, and that the principles of antisepsis must govern all procedures on the mastoid as well as in any other region of the body submitted to operation.

The Simple Mastoid Operation on the Infant and Young Child: The anatomical relations of the temporal bone in the infant and the young child are different from those present in the adult. The bone itself is not fully developed at birth, and varies sharply and distinctly at different ages. Consequently the technique must be modified to meet the anatomical peculiarities of the temporal bone in the infant and the young child.

Anatomical:* In our discussion of the surgery of the mastoid on adults, we did not find it necessary to detail the anatomical relations of the external auditory canal. But when dealing with the infant and the young child, this structure is of great

* We refrain from describing in detail the anatomy of the child's temporal bone, and merely call attention to those peculiarities which are necessary for a proper comprehension of the technique advocated.

surgical importance in locating and selecting the route to open the antrum.

External Auditory Canal: In the newborn, the external auditory canal is a relatively narrow slit, compressed from below upwards. Its osseous portion is represented by the superficies meatus—a portion of the squamous plate bent at an angle of about 150 to the remainder of the squamosa. This superficies meatus extends from the zygomatic root backwards, and together with the membrana tympani constitutes the upper wall or the roof of the external auditory canal. Contrast Fig. 17 with Fig. 18.

The concha is attached at its opening directly to the superficies meatus, so that one can hardly speak of a cartilaginous section of the canal at all in its upper (roof) wall at the time of birth.

As the child develops, the relations gradually change. The membrana tympani assumes a more vertical position, and the superficies meatus gradually forms a sharper angle until it approaches the adult type, namely a right angle.

Because of these changes, the sides of the canal almost in apposition at birth, separate, and the canal lumen widens. The edges of the membrana tympani move away from the neighborhood of the cartilaginous portion of the canal through the interposition of points of ossification from which the true bony roof of the canal develops.

The ossification takes place from the annulus tympanicus. At birth, this is an incomplete ring of bone; the incomplete portion representing a defect of from 1 to 2 mm. is spanned by the superficies meatus. The development of ossification proceeds unevenly, at first forming two bony thicknesses, the tuberculum tympanicum anticum and the tuberculum tympanicum posticum. From the two tubercles, the osseous development spreads until the bone growing from in front and from behind merges, usually leaving a defect which is still found at the end of the second year of life. This defect in ossification of the external auditory canal usually does not close until the fifth year of life, and occasionally remains for a much longer time; it has been found by *Burkner* (38) in 19.2% of 982 skulls examined by him.

FIG. 17.—SECTION THROUGH THE EAR OF THE CHILD (*after Gomperz*).

A, Superficies Meatus. B, Aditus. C, Cochlea. D, Jugular Bulb. E, External Auditory Canal. (Contrast it with Fig. 18.) F, Tympanic Cavity.

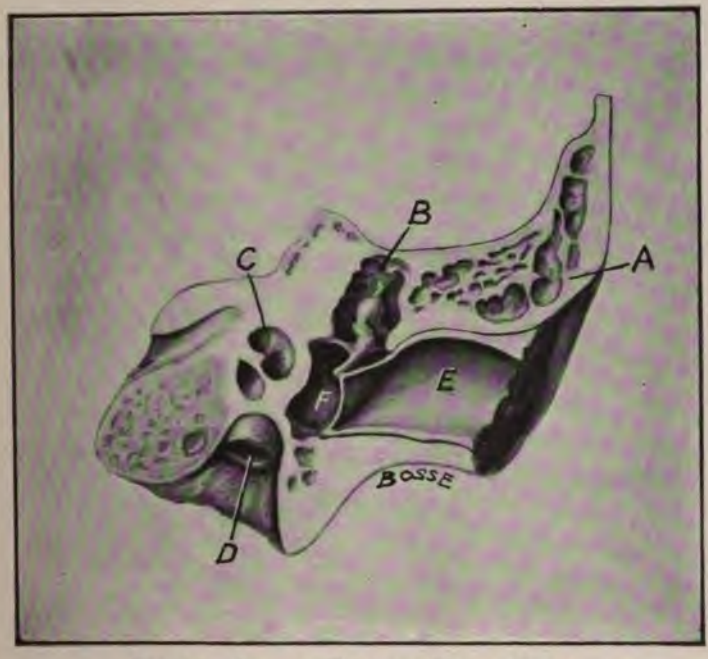

FIG. 18.—SECTION THROUGH EAR OF ADULT.

A, Squama (Mastoid Cells Shown). B, Aditus. C, Internal Ear. D, Jugular Vein. F, Tympanic Cavity (Lower Part). (Contrast this with Fig. 17.)

PLATE VII

The drum remains part of the external canal roof of the recessus meatus at this age (*Politzer; Tröltsch*). The osseous canal now develops and separates the cartilaginous section from the superficies meatus. The osseous portion of the canal is much shorter in the child than in the adult, although in its entirety, the canal is relatively as long as in the adult.

Symington (39) has shown the length of the canal at different ages to be as follows:

Age	Floor	Roof
2 months	17 mm.	13 mm.
6 months	19 mm.	14 mm.
1 year	20 mm.	15 mm.
2 years	22 mm.	16 mm.
5 years	23 mm.	17 mm.
6 years	24 mm.	17 mm.

From this table, the difference in the length of the floor and of the canal roof is shown at the various ages, and the angle of inclination of the membrana tympani which reaches from roof to floor is outlined. The canal is closely adherent to the superficies meatus and follows the contour of this section of the squamosa.

The Middle Ear: The middle ear of the child presents its most characteristic feature in the nearness with which the promontory lies to the membrana tympani, and in the presence of the many defects which are often found in one or other of the walls of the tympanic cavity.

The upper wall, the tegmen tympani, presents in the very young a fissure (the petro-squamous) situated between the petrosal and the squamous parts of the temporal bone. This suture is traversed by a process of dura which establishes communication between the lining membrane of the tympanic and the cranial cavity. Usually this opening closes at the fifth month of ossification. The floor of the tympanic cavity is a thin partition of bone, presenting many small defects and occasionally larger dehiscences. The jugular bulb is often found in direct contact with the lining membrane of the tympanic cavity in these cases. *Urbantschitsch* (31) holds that these defects are

quite common in children under five years of age, and my own experience has borne out his observations. (Fig. 19.)

The Mastoid Process: The mastoid process is very rudimentary at birth. It is situated as a small tubercle, close behind and somewhat above the external auditory canal. It becomes more pronounced as the child grows and gradually shifts its position to the rear of the external auditory canal; it is fully developed about the time of puberty. (See Fig. 20.)

The mastoid cells develop different characteristics in different children. Many authorities claim that the cells are absent in the mastoid process of the child. According to *Körner* (40) the total absence of pneumatic cells, together with the preponderance of diploetic cavernous spaces, is to be regarded as a sort of failure or disturbance of development.

The antrum is fully developed in the newborn, but no mastoid process is present at this time. The mastoid cells commence their growth from the antrum, at first backward; later on, toward the protuberance, until at the end of the first year, pneumatization begins. At the third year, the mastoid process may already resemble the adult type. In a case operated upon at 2 years of age, we observed a mastoid process which in no way differed from the adult type.

In the young, there is a tendency for the cells to group themselves anteriorly and posteriorly to a central plate of bone. In exenterating the cells, during operation, this central plate of bone may wrongfully be assumed to be the inner table. The possible existence of this anatomical structure in the young must, therefore be kept in mind.

Surgical Landmarks: Bearing in mind the anatomy of the external auditory canal, in infancy and in childhood, the line of incision which is to give approach to the middle ear spaces will have to be brought to a higher level than that maintained by the annulus tympanicus.

Upon separation of the soft parts, especial care must be exercised to separate the superior wall of the external auditory canal from the superficies meatus. This is so carried out that the annulus tympanicus is recognized. In the child—and here I may remark that the younger the subject, the more important

FIG. 19.—SPECIMEN (2½ YRS.) SHOWING:

Tympanic Cavity, C, Aditus, D, and Antrum Mastoideum, E, Laid Free. The Stapes is Seen in Position. A Bristle, A-B, is Passed Through a Defect in the Tympanic Floor, where the Walls of the Jugular Bulb were Found in Contact with the Mucous Membrane of the Tympanic Cavity.

PLATE VIII

this becomes—the annulus tympanicus is the first landmark to be sought for and recognized.

While some, *Oppenheimer* (41), and others, find it necessary to incise the canal wall for this purpose, I have never felt compelled to resort to such a procedure, and consider the possibility of infecting the cartilaginous and the soft parts of the external ear a positive danger when this is attempted.

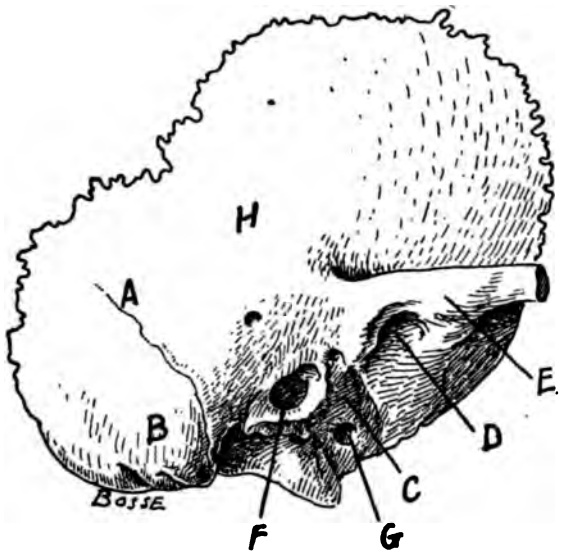

FIG. 20.—SURGICAL LANDMARKS (SURFACE) IN THE CHILD.

A, Squamomastoid Suture. B, Rudimentary Mastoid Process. C, Incomplete Ossification of External Auditory Canal Wall Showing Defect at G. D, Glenoid Fossa. E, Zygoma. F. Osseous Rim of External Auditory Canal.

On the external surface of the temporal bone, unossified, in the very young, we find the squamomastoid suture, extending downwards from a small distance above the temporal ridge, toward the lower extremity of the mastoid process, marking off the squamous plate from the more or less rudimentary mastoid process. This suture, more or less typically a juvenile structure, occasionally persists throughout life. (See Fig. 20.)

To prevent the knife from entering this suture to the possible damage of the underlying structures, we direct the primary incision toward the middle of the mastoid tip.

The squamomastoid suture marks the lower and the posterior limit of the descending plate of the squama; posterior to this, we expect to locate the sigmoid sinus. No matter how small the temporal bone, it is rare indeed to find the sinus further forward than marked out for it by this landmark.

As we have shown in dealing with the anatomy, the mastoid antrum and the middle ear are much nearer the surface of the skull in the young than in the adult; their relations to the overlying parts differs so much from those of the adult that other landmarks than those used for the latter must be relied upon to locate the antrum in the infant.

Neither the spine of *Henle* nor the suprameatal triangle is a sufficiently constant guide to the safe performance of the operation. The most constant guide in the child is the ridge of bone formed by the posterior root of the zygoma. This ridge, by its lower border, indicates the level of the mastoid roof above which a few lines in distance, the base of the middle cranial fossa is located. The ridge is sometimes designated the supramastoidal crest, and is formed by the obliquity of the angle derived from the auditory plate of the squama and the remainder of the squamous portion of the temporal bone. It is sufficiently constant to furnish a reliable guide to the upper limit of safety in entering the antrum, and to aid the surgeon from adventitiously opening into the cranial cavity. If we attempt to locate the aditus upon the external surface of the skull, we find it, at this age, directly superior (above) the membrana tympani, almost in the middle of the arch of bone formed of the superficies meatus where it spans the opened ends of the incompleted annulus tympanicus. Posterior to this arch, the antrum is located, inclining slightly toward the back of the head. As the child grows the antrum assumes a position more and more posterior to the external auditory canal.

Our site of election for entering the antrum is therefore, located at a point a few lines behind and somewhat above a plane drawn through the malleus handle.

To complete the surgical anatomy of this operation in the young, we must note that the point of emergence of the facial nerve from the skull is very superficial, and during the retrac-

tion of the soft parts, and also during the primary incision, the knife or the retractor must be carefully guided as the lower boundary of the mastoid is reached lest the blade sink into the tissues and sever the nerve. During the opening of the antrum, danger of injuring this nerve is avoided by noting the above described landmarks, when locating the juvenile antrum, because the opening is then made at a point where the overhang of the horizontal semicircular canal protects the nerve from injury.

The Operation on the Infant and Young Child : The primary incision is made from below upwards. Starting directly over the middle of the mastoid tip, the incision is carried with one sweep of the knife, cutting through the soft tissue and through the periosteum to the bone, in a curvilinear line toward the auricular attachment, which is followed upwards to its upper pole. The incision is placed at about ¼-inch distance from the auricular attachment.

By making the incision from below upward, we guard against injury to the facial nerve at its point of emergence from the skull, and also prevent the knife edge from inadvertently entering the squamomastoid suture, should this be widely open, or situated rather far forward. The incision made in this way causes the knife to cross the suture line and not parallel its direction—a distinct advantage.

The soft parts are gently retracted; the periosteum is pushed backward beyond the squamomastoid suture, and the anterior lip of the wound is pushed forward and downward, the auricle meanwhile being bent forward upon itself. The external auditory canal is separated at its roof from its adhesions to the superficies meatus; the concha and the canal are then pushed forward and downward until the membrana tympani is recognized. The latter must positively be identified.

The bleeding points have meanwhile been secured, and the open lips of the wound are held apart by a suitable retractor (the *Allport-Jansen* best serving the purpose).

The surgical field is now in full view, so that the landmarks can be identified. The zygomatic root, the ridge extending backward from it, and the squamomastoid suture are recognized. The site of election for entering the antrum is now determined,

unless a fistulous opening already points the way to the suppurating interior.

As described above, the posterior part of the bony arch spanning the upper margin of the membrana tympani is broken through with a few light taps of the hammer on a small curved chisel. In the very young, the curette may be used to make the opening. The opening is made at a point a few lines behind and above the plane held by the position of the malleus handle. The cortex is usually exceedingly thin and easily broken. Occasionally, the so-called "spongy spot" is plainly discernible, and many surgeons follow this as a guide to the antrum. We do not consider this a reliable guide, for the bones of children are so vascular in structure that the spot is not sufficiently differentiated from the surrounding bone. Others place their reliance upon *Henle's* spine, or upon the fossa behind it, and while it is a fact that many specimens show these landmarks plainly, they form no reliable guide to the antrum at the age under discussion.

The antrum entered, the cortex is rapidly removed with a rongeur or a curette, working downward and backward toward the mastoid tip which, depending upon its condition, is either entirely removed or only shelled out. Working upward from this, we approach the squamomastoid suture, and uncover a hard plate of bone. The cells and their contained detritus are eviscerated as we proceed. The hard inner table is uncovered and limits our procedure at this point. We continue along, following the inner table, to outline the sinus to the knee, and from this we eradicate the cells lying above and to the rear of its outlines. The evisceration of the cells continues, working upward until the roof of the mastoid is reached; in proceeding forward, we remove the tegmen cells as far as the zygomatic root, and finally also clean out the cells in this region. In operating along the tegmen, we exercise care not to penetrate the petro-squamous suture, which may possibly be open.

Finally, we deepen the bone cavity until all evidence of disease is removed.

At the completion of the bone surgery, we have an irregular-shaped cavity extending from the tegmen above to the tip below, with its upper anterior extremity overhanging the

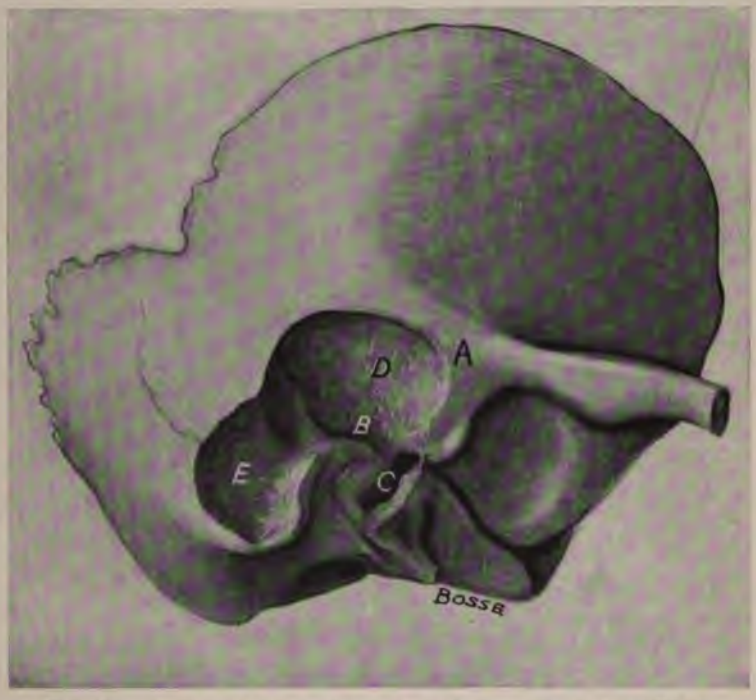

FIG. 21.—SIMPLE MASTOID OPERATION COMPLETED ON THE BONE (CHILD, 2 YRS.)

A, Zygoma. B, Opening into Antrum. C, External Auditory Canal. D, Tegmen Laid Bare, After Removal of Zygomatic Cells. E, Shell of Rudimentary Mastoid Process.

PLATE IX

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external auditory canal, and coinciding in depth with that of the inner table.

The antral boundary is marked by the presence of the hard, white outline of the horizontal semicircular canal.

We never curette the antrum itself, but content ourselves merely with providing drainage. The use of the curette in the child's antral cavity, or in the aditus, in view of the smallness of the parts, may result in ossicular dislocation, a risk too great to incur.

The operative procedure is finished by placing a loose tamponade of a single strip of gauze into the wound cavity, pleated to fill it and to act as a drain, but not packed too tightly. A second strip of gauze is placed in the external auditory canal, and the outer dressings are then applied.

Personally, we are in the habit of flushing the wound thoroughly with hydrogen peroxide, followed by a solution of bichloride of mercury, before introducing the tamponade.

Faults of Technique: The osseous canal being less and less evident as a distinct anatomical structure, the younger the subject, the part played by the squamosal plate assumes greater importance. As a result of the canal being attached at its roof to the superficies meatus, in comparison with the position of the membrana tympani, the auricle is situated high, and a common fault of technique is failure to detach the canal roof from its bony support. Because of this technical error, the cranial cavity is often unnecessarily opened.

Contrary to the condition in adults, where the antrum is usually located higher than is supposed, in the child it will be found, relatively speaking, lower, if the primary incision is not properly placed, and the soft parts carefully separated from the superficies meatus. The squamosal plate will often incline at a very acute angle, instead of occupying an almost vertical position, and this angle causes the linea temporalis practically to overhang the external auditory canal. When such is the case, the overhang might possibly be mistaken for the temporal ridge, and the surgeon mistaking his guide, unnecessarily opens the cranial cavity.

Gentle persistence in retracting the soft parts until the mem-

brana tympani becomes recognized will reveal the unusual position of the ridge, and this technical error will be avoided.

Study of the Operative Findings During Mastoidectomy : When the operation is undertaken at the very onset of the mastoiditis, the cortex, when opened, will reveal an intensely hemorrhagic field. Except, perhaps, in the immediate neighborhood of the mastoid antrum the cell walls are not as yet broken down. Nor when opened do they generally evidence the presence of fluid pus, but rather present a swollen, tumefied condition of the lining mucous membrane, with a cell here and there containing a small drop of pus.

Later in the disease, the opened mastoid reveals great cellular destruction, especially about the antrum; many intervening cell walls have broken down and have formed large cavities. Often this is also found to be the condition about the tip cell. In cases of longer duration, the entire mastoid cavity may be found to form one large suppurating cavity, with purulent tracts leading toward the sinus or the dura; both these structures may be involved in the advance of the purulent process.

When fluid pus is uncovered upon opening the cortex, its behavior as it wells up from the interior is often significant of the condition in the bony cavity. When it slowly oozes from a small opening in the cortex, the inference is, that cell disintegration has not proceeded far; on the other hand, if the pus wells up in large quantities, and rapidly reappears after removal of the overflow, but evidences no pulsation, then the conclusion is evident that extensive purulent disintegration is present. The bounding bony walls of the suppurating cavity are evidently still intact.

If the fluid pus flows rapidly and copiously, and in addition pulsates markedly, or as *Whiting* remarks, is expelled in little jets, the inference is that the inner table of the skull has been broken down, and in addition there is present a purulent disintegration of the interior of the mastoid. This means that the meninges or the sinus wall is exposed—the condition being one of extra dural or perisinus abscess.

Occasionally, pulsating pus is seen in cases of purulent disintegration of the interior of the mastoid, where excessive

granulations are present within the coalesced cells. The pulsation is imparted to the pus from the blood-vessels in the soft granulations. Later, during the operative procedures, when the parts have been carefully cleansed, and the sinus wall sharply outlined, if we find a smooth, intact wall, we presume, unless other developments supervene, that we are dealing with a healthy sinus. Where fragmentary, irregular, fibrous shreds are found attached to the sinus wall, which are tenacious in their attachment, that is, they are hard to wipe away, suspicion is aroused of a perisinus abscess. With such findings, the sinus wall should be subjected to rigid inspection, and if symptoms from it are present, the bony wall should be opened.

Where we find the cortex thick, and the mastoid cavity showing lack of pneumatization, after the uncapping of the antrum, more than ordinary care is demanded to trace the few suppurating fistulous tracts to their ultimate terminations. The harder the cortex, the greater the resistance it offers to the advance of the pus toward the exterior, and consequently the greater the possibility of invasion of the deeper structures.

Finally, erosions of the semicirculars should be carefully noted, *but not probed;* such cases demand careful watching to recognize the first signs of intralabyrinthine involvement. We advise against probing such erosions, because of the possibility of thus breaking down protective adhesions which, if left undisturbed, may save the labyrinth from general infection

In children, the presence of cheesy, degenerated glands, uncovered during the integumentary incision, or the finding of a periosteum mottled in appearance, signifies tuberculous involvement (*Gomperz*, 42). The uncovering of discolored, sugar-coated looking bone, or the finding of sequestræ, signifies tubercular disease, especially when found associated with thin pus and cheesy degenerated granulations.

Gomperz cites it as significant in tubercular involvement of the mastoid among children, to find evenly distributed purulent discolorations in the periosteum over the mastoid, with no swelling evident, and the mastoid cells more or less full of a rather thin, watery pus.

After-treatment: The patient is put to bed, and efforts are at once instituted to combat shock and to ameliorate the after-effects of the anæsthetic. If the operation has been of long duration, and if its performance has demanded an unusually long use of the chisel—usually where extensive eburnization has caused a thickened cortex, then the bed should be warmed and suitable stimulation administered.

Repeated small doses of hot water relieve the nausea and the vomiting following the anæsthetic, and in extremely nervous or highly sensitive individuals, the exhibition of morphia hypodermatically, will often ease the first day following the operation.

In cases where a large quantity of blood has been lost during operation, and where the patient gives evidence by his appearance before operation of suffering from beginning sepsis, a large high enema of normal salt solution is of undoubted benefit.

The outer dressings, especially the retaining bandage, may be changed on the day following the operation for cosmetic reasons, but the wound proper should be left undisturbed for from five to eight days, depending on local and general conditions.

If no fever develops, and the post-operative temperature remains within safe bounds—for details see below—and the patient has neither pain in the affected ear, or unbearable headache, then the dressings should be left intact until the mastoid wound begins to secrete. The secretion usually appears between the fourth and the eighth days, varying in different individuals.

On the day following the operation, the dressings may be soiled by blood which oozes from the wound. The change of the outer dressings, by presenting a clean bandage to the eye of visiting friends and the patient's family has a reassuring influence on the patient.

If an unpleasant odor is perceptible from the dressings, or if pain is complained of, or if an unaccountable rise in temperature is noted, the wound requires immediate inspection, and all dressings and packings should be removed to permit a minute examination of the entire operative field.

At all changes of dressings surgical asepsis should be the goal aimed at, and every piece of gauze, each instrument, as well as the surgeon's hands, should be as rigorously prepared as they

were for the operation itself. We observe, especially in dispensary work, many a mastoid wound presenting, at the first few dressings, bright, clean granulations, which gradually change in character and show excessive secretion and finally local infection because of inadequate preparation or careless handling along lines of antisepsis.

At the first dressing, the wound edges should look fresh, the granulations should be red, of firm consistency, and the gauze, upon its removal, should be moist only and not soaked by secretions. The gauze drain in the external auditory canal should be slightly damp. When these are the conditions found at the earlier dressings, everything is progressing favorably.

The wound is again packed with a clean strip of iodoform gauze up to the skin level, on top of which plain gauze is placed. After the external auditory canal has been cleaned, it is lightly repacked, external dressings are applied and the bandage is replaced.

The dressings should be changed as rapidly as possible, thus lessening the possibility of infecting the wound by long exposure to the air. The second dressing is undertaken in three or four days; thereafter, usually every second day until healing is completed.

With the exception of old people who may be permitted to sit up as early as their strength will allow, the patient is kept in bed for the first week. Old people are usually enervated, and the reaction of their tissues impeded by too much bed rest. In the very corpulent, or those in whom bed rest aggravates pulmonary stasis, the semirecumbent position is allowed upon the third day.

Healing by granulation should be permitted to proceed without interruption; in a clean, healthy, granulating wound, there is no indication for repeated use of antiseptics.

The less they are employed during the post-operative period the more rapidly does healing take place. As long as pus, coming from the middle ear, is in evidence, so long must the antrum be kept open. As soon as the secretions from this region have stopped, the closure of the wound behind the auricle may be encouraged.

The tamponade, it is to be remembered, should be as loose as is consistent with keeping the wound open for the requisite time. Many a post-operative period has been unduly protracted because of a tight tamponade. As the post-operative period advances the edges of the cutaneous wound show a tendency to turn inward. If this is allowed to proceed unchecked, the cosmetic after-effects will be poor; they usually result in a more or less pronounced depression.

To prevent this, the skin edges must be prevented from turning in. Usually this tendency becomes apparent in the third or fourth week of the post-operative period; the skin edges should then be carefully separated from the underlying tissue, and loosened all along its margins, both anteriorly and posteriorly. Gauze is inserted under this raised edge, and the skin kept away from the underlying tissue until the granulations have reached its level. When this little procedure is successfully carried out, there usually will be but little depression apparent in the final appearance of the healed wound. The separation of the skin is carried out under cocaine anæsthesia.

I have found the application of silver stick to the skin edges at changes of the dressings very efficacious in checking the tendency toward this turning in. Sometimes, exuberant granulations on the wound lips, if permitted to remain *in situ*, will check the ingrowth of the epithelium and prevent subsequent depression.

Exuberant granulations, wherever evident in the cavity proper, must be checked by application of the silver stick, or silver in solution, or by tight tamponade for a short period. After the simple mastoid operation healing is usually completed in from 6 to 8 weeks.

Blood Clot After-treatment: When the blood clot after-treatment has been elected, the outside dressings are daily removed for the first week to afford inspection of the wound. The edges must evidence union by primary intention, which when once firmly established, permits removal of the outside dressings and bandages, a light coating of collodion being placed over the scar line. The middle ear should be dry at the end of the first week, and the mastoid wound should feel hard and firm in about ten days.

Upon the first advent of signs of a disintegration of the clot, or if the aural discharge is excessive and has a foul odor, the wound should be opened, cleansed with antiseptics, and subsequently treated by the open method.

The Significance of Post-Operative Temperature: Following simple mastoidectomy, there usually is a distinct febrile reaction which occurs during the first forty-eight hours. This is in itself of no significance. Fever is generally more marked when the operation is of long duration, and is accounted for by assuming absorption of broken-down detritus from the wound edges. A rise in temperature is usually seen in cases where the soft parts have suffered traumatism during the operative procedures.

In this connection, it is of interest to recall the study of *Harris* (43) who reported an analysis of 100 uncomplicated simple mastoid operations. He found that of these, only one case ran a perfectly afebrile temperature; that the post-operative temperature generally lasted from two to nineteen days, the average being 6.65 days. In 65 of the histories studied by him, the highest point reached by the temperature curve took place on the second day; in 29 cases, it occurred on the third day, and in the remainder (15 cases) it either appeared on the fourth day or thereafter.

The temperature ranged at its point of greatest severity from 99 to 104 F., the patients being, however, very comfortable in spite of the temperature elevation.

In detail, his findings were as follows:

No. of Cases.	Highest Range of Temperature.
28	99-100 F.
38	100-101
23	101-102
6	102-103

In the remainder it ranged still higher. The continuation of the temperature gave the following results: In 56 cases it persisted less than one week; in 10 cases it lasted only three days; in 18 it was noted for four days, and in 12 other cases it continued for only five days. Among the remainder of the cases, the rise of temperature persisted for periods varying from six to nineteen days.

Barring other symptoms, post-operative temperature is without special significance. It demands a more frequent change of dressings to prevent absorption into the general system of secretions from the wound. Where fever was present prior to operation, it usually falls immediately thereafter, sometimes rising again on the second day. (See Chart II.) A second recurrence of temperature after a fall is to be regarded suspiciously, especially if the second elevation equals in height the first rise of temperature.

We append temperature charts selected as more or less typical of post-operative temperature curves. It will be noted that in every case the drop is more or less gradual, extending over a longer or shorter interval. (Charts I, II, and III.)

A sudden rise of temperature, after the third day, is not to be lightly considered. The bowels, the lungs, and the wound require careful examination, especially if the patient is at all restless, or appears uncomfortable. In young children, the temperature reactions are more marked than among adults, and the gastro-intestinal tract will more often demand attention. The development of post-operative pneumonia is shown on Chart No. IV. Intercurrent diseases make their presence known by a rise of temperature.

A rapid rise, followed by a chill and a rapid drop, to be again followed by a rise equally high, is significant of sinus involvement; such a temperature curve is especially suspicious when headache or other symptoms supervene.

Meningeal involvements usually show a temperature elevation which gradually increases, and then remains steadily high; concomitant symptoms, more or less significant, meanwhile develop. (See Chart V.) The temperature of brain abscess whether cerebral or cerebellar does not present anything characteristic of the disease, but is rather significant of the meningeal involvement surrounding these lesions.

Finally, we conclude that, although temperature elevation is always to be watched, expectant treatment is indicated until general and characteristic symptoms develop sufficiently to determine the diagnosis and the therapeutics required in each given case.

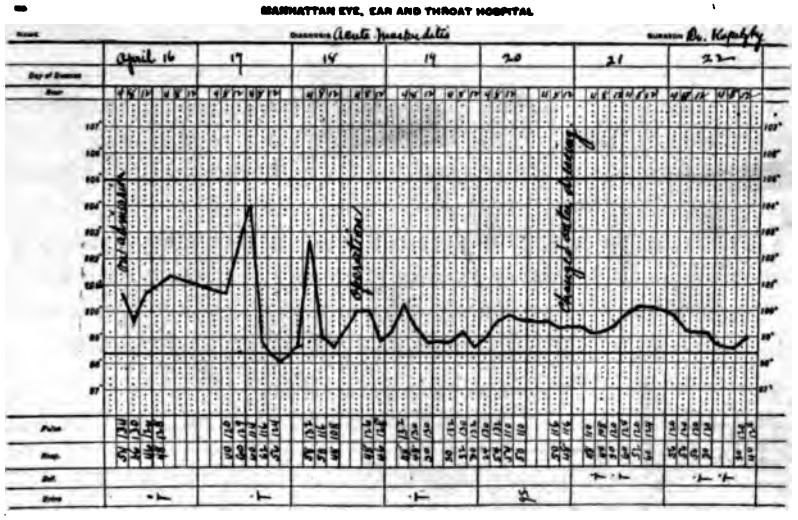

CHART I.—Showing Temperature Curve in Case of Acute Mastoiditis. The High Temperature Before Operation in the Child Is Here Shown.

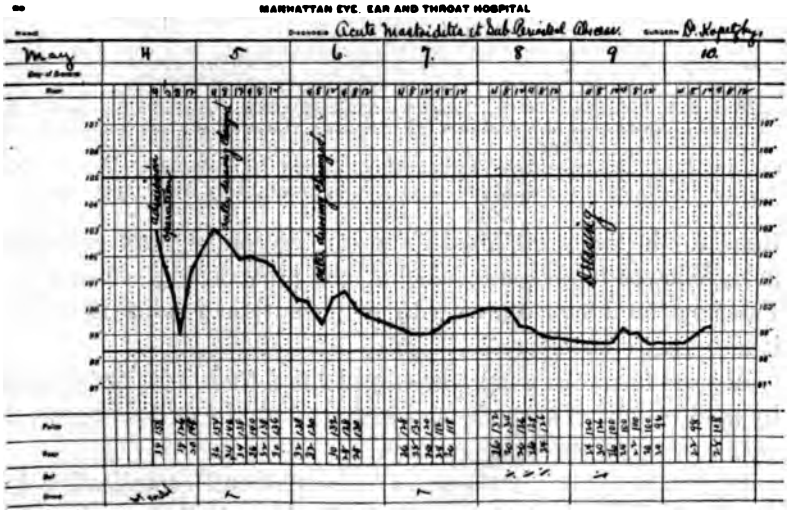

CHART II.—Showing Post-Operative Temperature Curve After Simple Mastoidectomy. The Temperature Rose on Day Following Operation and Thereafter Gradually Dropped.

Wound Complications: Wound complications may arise at any time after the operation. Generally speaking, these are to be classified as local infections, iodoform dermatitis, and local abscess formations in the immediate neighborhood of the wound edges.

The local infection may result from a secondary infection occurring adventitiously during changes of dressing or during the operation. They usually subside under treatment with wet bichloride of mercury dressings, and other suitable local applica-

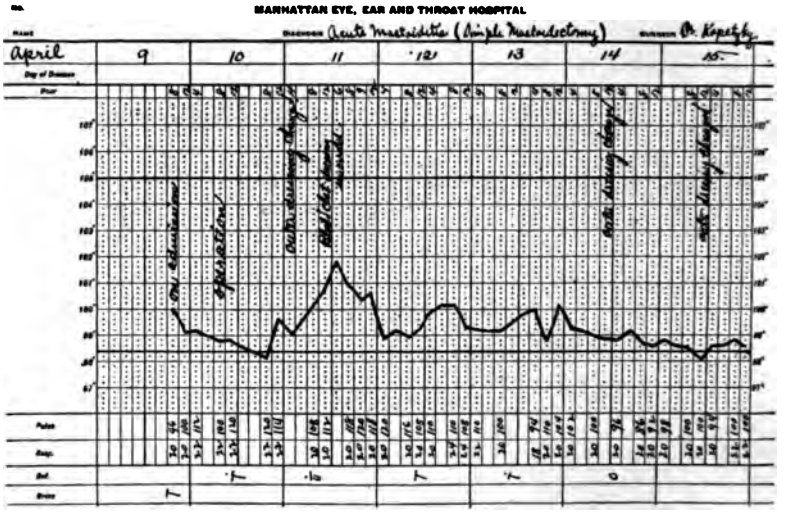

CHART III.—Post-Operative Temperature Curve (Simple Mastoidectomy). Rise of Temperature Shown on Afternoon of Second Day After Operation.

tions to the inflamed area. The application of pure carbolic acid, followed by absolute alcohol has proved very successful. Painting the inflamed area with 10% solution of iodine in water is also very efficacious.

Abscess formations must be emptied and their interior treated by applications of carbolic acid and alcohol, the outside covered with wet dressings for a few days.

Erysipelas: By far the most serious wound complication is that caused by erysipelas. When this infection occurs it presents an area of inflammation sharply demarcated at its line of advancement from the surrounding tissue. As it progresses, an

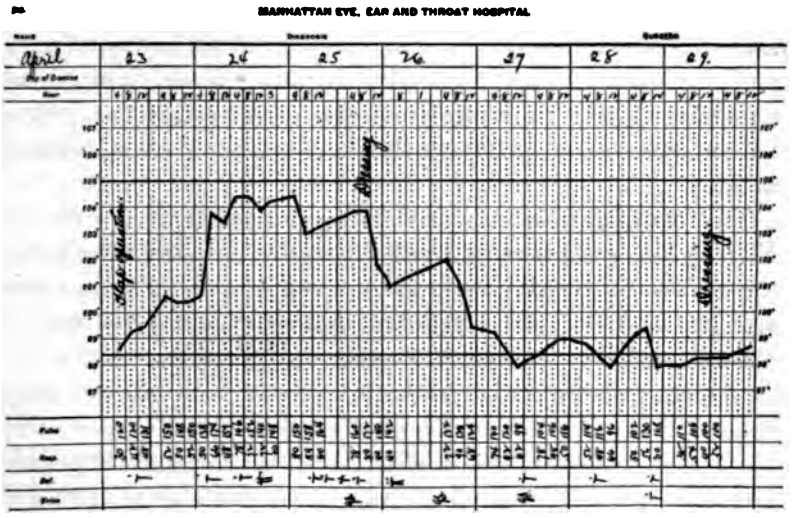

CHART IV.—Temperature Curve of a Case of Ether Pneumonia Following a Flap Operation.

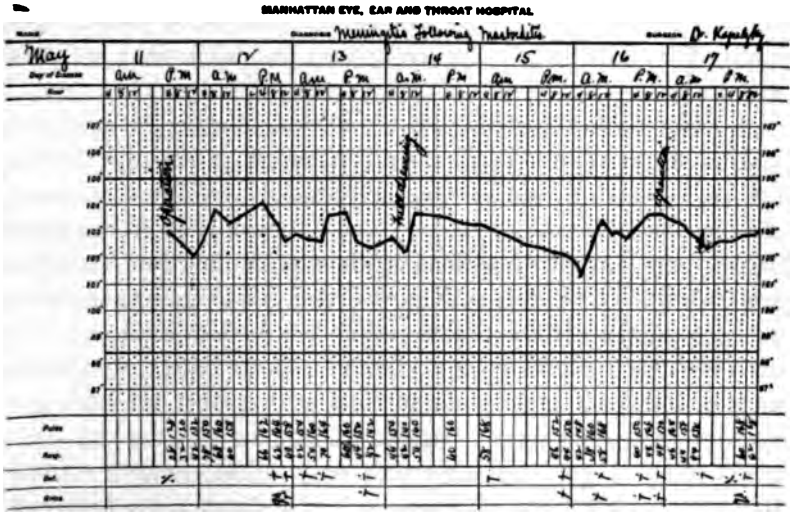

CHART V.—Showing Temperature Curve of Post-Mastoidal Meningitis. The Operation Marked on Chart Refers to the Exploratory Procedures to Drain the Meninges.

area of healthy skin becomes visible between the inflamed area and the wound; the neighboring lymphatics are outlined as reddened streaks radiating from the area of infection. The patient generally exhibits constitutional symptoms—prostration and fever, etc.

The following mixture, which I owe to a suggestion of *Dr. L. K. Neff*, has yielded most beneficial results, and usually checks the advance of the disease in twenty-four hours. Mistura creta aromatica (B. P.) and glycerine are freshly mixed to form a paste having the consistency of molasses. To this we add sufficient pure carbolic acid crystals to make a 10% solution. This is painted over the inflamed area and left in place for 12 hours; the parts are then bathed in alcohol and the mixture reapplied. The application of the mixture is continued a day or so after the temperature has dropped, and it should always be painted beyond the inflamed skin. Internally, adrenaline chloride (1:1000 in qtt. X doses) is administered every four hours. The application of ichthyol has been found of benefit by some, and the writer has also checked the advance of an infection of erysipelas by swabbing the mastoid wound with a weak watery solution of iodine, and painting the inflamed skin area with the iodine tincture, reapplying the tincture twice daily. Recently the administration of antitoxine has been tried and has given good results.

As we well know certain patients cannot tolerate the administration of iodoform. While we use iodoform gauze only for the first and second dressings, because it tends to produce exuberant granulation, still many patients complain even then of annoying itching and burning sensations in the wound, and sometimes we are astonished to see when the first dressing is changed evidences of a dermatitis. In such cases we replace the iodoform gauze at once with plain sterile gauze. In children, we limit the employment of iodoform gauze even at the first dressing; we wash the iodoform gauze in sterile water to dilute its strength, and content ourselves with placing a strip only in the antrum. After the first dressing, we dispense with it entirely, except where excessive odorous discharge, or possible putrefactive reaction is to be combated. In such cases, the application to a mixture of

equal parts of liquid vaseline and castor oil to the wound has been found helpful.

Indolent granulations require stimulation, either by iodoform, balsam of Peru, or other means. It not unusually happens, as the granulations reach the level of the skin, that during the last weeks of the post-operative period, that the wound appears to make no progress whatsoever. In such a contingency, the entire removal of the bandage and of all the dressings, and the exposure of the wound to the sunlight and air will give surprisingly quick results. A slight dusting with aristol or some other antiseptic powder is all that is required in these indolent cases.

During the last of the post-operative period, after the perforation in the membrana tympani has healed, and sometimes even before the post-auricular wound has completely closed, the patient may complain of an annoying tinnitus, and often of some deafness. Careful and cautious Eustachian catheterization is now employed, three times a week, and continued for as long a time as the symptoms demand. Such treatment usually results in the restoration of hearing, and also in relieving the tinnitus by re-establishing the balance of air pressure on either side of the drum membrane.

The pharyngeal vault and the nares must be carefully cleansed of all secretions before catheterization is attempted.

Results of the Operation: When simple mastoidectomy is properly performed, and all the diseased cells eviscerated and when the after-treatment is correctly carried out, the results of the operation are highly satisfactory, not only in its effect upon hearing, but also in saving the life of the patient.

Simple mastoidectomy does not preclude subsequent middle ear disease, and a recurrence of an acute middle ear empyema with infection of the newly formed tissue filling in the mastoid shell is a possibility. I have observed such reinfections to occur especially in badly nourished children, and in those having adenoid vegetations in their pharyngeal vaults.

Bone Regeneration: That some regeneration of bone takes place in the mastoid shell has been demonstrated in cases where, because of persistence of distressing otorrhœa, I reoperated—in one case after twenty months, and in another case after one year,

and in a third case after six months. Here I found that newly formed bone had been deposited in the mastoid shell, replacing the fibrous connective tissue. This new bone was of a vascular nature and darker in hue than the remainder of the osseous tissue. To encourage new bone deposits, it is important to save as much of the periosteum as possible when operating.

In a case of acute otitis media purulenta which recently came under observation the middle ear became infected subsequent to an operation for the removal of adenoids, and the old wound broke down a second time. At the operation, which was undertaken to eviscerate the infected tissue in the mastoid shell, extensive regeneration of bone was noted. The entire bone cavity had shrunk to such an extent, that only a small opening filled with granulations was seen leading in a direct tract to the antrum. This observation becomes important when the second operation is undertaken by a different surgeon than the one who performed the original operation, and when understood will perhaps prevent an unjust criticism of him who performed the first operation. When looking at the bony cavity presented by the case above described, had I not been fortified with the notes taken at the first operation, the tendency would have been to describe it as having been poorly performed because of incompleteness. I had the same assistants at both operations, and the fact of the unlooked-for bone regeneration became clear to all of us.

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CHAPTER VII

THE RADICAL MASTOID OPERATION

Historical—Anatomical—Indications for the Radical—Counter Indications—When to Operate—Objects of the Operation—Preparation of the Patient—The Bone Operation—The Stacke Procedure—Advantages of the Stacke Procedure—The Zaufal Operation—Operative Field—The Operative Procedure on the Infant and Young Child—Radical Mastoid Operation Modified so as to Retain the Ossicles in Situ—Operative Findings—Accidents During the Operation—Faults of Technique—The Plastic Flap (Stacke Flap—Panse Flap—The Siebenmann Flap)—Thiersch Skin Grafts—Technical Errors During the Plastic Procedures—Choice of the Plastic—After-treatment—Results of the After-treatment—Unusual Happenings During After-treatment—Estimation of Results of the Operation—On the Hearing—Results of the Radical—Procedures to Close Persistent Post-auricular Openings.

Historical: In 1873, *v. Tröltsch* (1) suggested a modification of the *Schwartze* operation, in its essentials identical with the present radical operation. Although his suggestion is recorded, owing to the indefinite indications advanced by him for its employment, it did not gain recognition as a new procedure.

Both *Schwartze* (2) and *Körner* (3), in the operations reported by them, either removed the whole or part of the posterior canal wall, because of conditions found during operation, and essentially performed the radical operation. They did not, however, describe it as a new procedure, nor did they not lay down the principles governing its employment: it remained for *Küster* to enumerate the steps upon which the radical operation is based.

Küster (4) advocated that the bony cavity be widely opened, that all diseased tissue be removed, in order to reach the source from which the purulency proceeds, and permit free drainage of

the pus. He modified the *Schwartze* operation by recommending the fundamental removal of the posterior osseous canal wall in cases where the primary purulent inflammation centered in the tympanic cavity. Upon this foundation the radical mastoid operation is based.

His first description of the operation, however, is somewhat obscure; he says nothing of removing the lateral (outer) aditus wall. This was first brought to the attention of the profession by *v. Bergmann* (5), who not only opened the mastoid, but simultaneously removed the posterior and portions of the upper osseous canal wall. *Bergmann* was the first to designate the procedure "The Radical Operation."

A full and very detailed account of the operation, with the exception of the formation of skin flaps, appeared from the pen of *Zaufal* (6) and *Jansen* (7). Continental authorities called the procedure the *Zaufal* operation. *Jansen* (8) himself modified the procedure in cases where "caries was found posterior to the margo tympani post. near the canalis facialis," advocating the removal of the margo tympanicus posterior, where it protrudes beyond the facial canal, and bridges the lower posterior corner of the tympanic cavity. He advocates removing as much of this bony bridge as possible, being halted by facial twitching. If the disease is localized in the hypotympanum, and the floor of the tympanum lies deeply, then he advocates the removal of the margo tympanicum inclusive of the respective canal walls, until an absolutely free opening at the posterior and lower part of the tympanic cavity is obtained.

Stacke's (9) claim to originality rests upon two foundations. He advocated opening the bone from within outward. After loosening the skin and the periosteum of the upper and the posterior canal walls, he first enters the tympanic cavity, then the aditus, and finally reaches the antrum, employing a "protector" —an S-shaped narrow raspatorium—which he places in position on the lateral (outer) wall. He uses a chisel to remove the bony parts. The second original suggestion for which he is entitled to credit is the formation of a flap from the skin and the periosteum of the posterior and the upper canal wall, and the introduction of this flap into the wound cavity.

This presents two distinct advantages: first, it secures a persistent skin-covered cavity between the canal and the antrum, and secondly, it induces epidermatization of the wound cavity.

Skin transplantation according to the method of *Tiersch* was first recommended by *Siebenmann* (10) to better procure a more rapid healing in the wound cavity. Other surgeons have advanced various other skin flaps and modifications (*Schwartze* (11); *Panse* (12); *Grünert* (13)).

Many minor changes have been advanced by American and foreign authors; it is too early as yet to determine the value of these suggestions.

Anatomical: The anatomy of the mastoid process is described in the chapter on the simple mastoid operation; in order intelligently to carry out the surgery of the radical operation, a description of the tympanic cavity is necessary. Not only does this cavity enter into the operative wound, but the purulent diseases of the temporal bone begin either in the tympanic cavity or in the adjacent pneumatic cells of the mastoid process.

The Tympanic Cavity: The tympanic cavity is shaped like a low prism; from five of its six sides the enclosed pus may extend either directly or indirectly toward the cranium. The lateral (outer) wall is the only exception to this rule.

Upper Wall: The upper wall or the roof of the tympanic cavity—the tegmen tympani—forms the floor of the middle cranial fossa. It is derived not only from the tegmen tympani, but also from a small part of the os squamosa. In the newborn, it presents a fissure—the fissura petro-squamosa—which extends backwards and can be demonstrated along the roof of the antrum mastoideum.

Extending through this fissure, a process of dura comes into relation with the lining membrane of the tympanic cavity. It transmits branches of the middle meningeal artery. This fissure usually closes at the fifth month of life; thereafter its remains are identified as the sutura petro-squamosa. The bony roof of the tympanic cavity is often exceedingly thin and transparent, and occasionally presents defects. *Bürkner* (14), examining 765 skulls, noted such defects 167 times, and *Körner* (15) found them present 18 times in 209 skulls. The tegmen tympani has been

observed, on the other hand, occasionally to be several millimeters in thickness. This has been seen to be specially the case in dolichocephalic heads, *Körner* (15); where the tegmen is thick a layer of small air spaces is found adjacent to it; some of these air spaces may, however, lead toward dehiscences.

The Tympanic Floor: This constitutes the floor of the tympanum and the roof of the fossa jugularis, and separates the tympanic cavity from the jugular bulb. In the newborn, this wall is generally a very thin, transparent plate of bone, which often present defects, thus bringing the tympanic mucous membrane in direct contact with the walls of the jugular dome. Dehiscences of the tympanic floor occur in about 4.8% of cases. In the adult, its thickness is proportional to the growth and the development of the fossa jugularis. (See Figs. 17, 18 and 19.) The floor is also characteristically traversed by ridges running from the membrana tympani toward the labyrinthine wall. The floor is usually deeper than the level of the floor of the external auditory canal, and sinks abruptly at the annulus tympanicus.

Differences have been noted on both sides of the head. Thus *Körner* finds among 449 skulls, that the floor is deeper 58.8% of times on the right side and 24.3% of times on the left side. It was an even level in 16.9% of times.

When the bony partition forming the tympanic floor is thick, it will usually be found to contain air cells. Sometimes when these air cells are partially or completely absent the fossa jugularis protrudes upward into the tympanic cavity, and the level of the tympanic floor is then higher than the level of the floor of the external auditory meatus at the annulus tympanicus.

Anterior Wall: The close relationship of the carotid artery to the tympanic cavity is characteristic of the anterior wall. It is separated from the tympanic cavity by two small canals—the canaliculi carotico-tympanici—which transmit nutrient blood-vessels from the carotid artery to the mucous membrane of the tympanic cavity. Veins likewise run from the tympanic cavity toward the carotid artery in the canals of the anterior wall, and finally anastomose with the sinus cavernosus (***Rektorzik, Rudinger, Block***—quoted by *Körner*).

The wall between the carotid and the tympanic cavity varies in thickness. At times it is found to be exceedingly thin, presenting instead of a series of canaliculi for blood-vessels, small openings through which the vessels come. Dehiscences are not uncommon along the carotid wall, and when they are present, the mucous membrane lining the tympanic cavity comes in direct contact with the carotid artery. *Körner* noted this condition twice in the observations, reported by him, and *Max* (17) observed the pulsations of the carotid through these openings.

Urbantschitsch in the third edition of his text-book (page 308) reports that he found in certain of the temporal bones examined by him, bony air spaces in the neighborhood of the tympanic orifice of the Eustachian tube; these led to a system of pneumatic cells, and spreading to the tip of the petrosal pyramid, communicated through dehiscences with the middle cranial fossa. I have never found the cells extending so deep in the many examinations which I have undertaken.

The orifice of the Eustachian tube is situated on the anterior wall and it is usually surrounded by small air spaces.

The Inner or Labyrinthine Wall: The inner tympanic wall constitutes the outer wall of the labyrinthine capsule. The lower half of this wall is formed by the bony capsule of the cochlea—its first turn. This is designated, the promontory; posterior and above it is marked off by the fenestra ovalis and the eminentia stapedii, the latter presenting an opening for the stapedius muscle. Below and posteriorly the promontory is limited by the fenestra rotunda. The fenestra ovalis contains the foot-plate and annular ligament of the stapes, and the fenestra rotunda contains the membrana tympani secundi. Behind and above the fenestra ovalis is a crest of hard bone formed by the facial canal. This crest often evidences dehiscences; these bony gaps are filled by fibrous membrane in direct contact with the tympanic mucous membrane. These fibrous gaps are often mistaken during operation for the facial nerve.

Above and behind the facial crest is a second hard bony crest, formed by the ampulla of the horizontal semicircular canal.

The Posterior Wall: The posterior tympanic wall presents the opening of the tympanic cavity into the antrum mastoideum

above. This opening is found at the same level as the aditus ad antrum. The roof or superior boundary of the one being continuous with the roof of the other. The floor of the antral opening is marked by a protuberance of the facial canal.

The posterior tympanic wall furthermore presents an elevation —the eminentia pyramidalis—within which the stapedius muscle is situated. The eminentia pyramidalis is both on the labyrinthine and the posterior-tympanic wall. Through its ramus it comes into relation with the facial nerve.

Outer (Lateral) Wall: This is formed by the membrana tympani, and has been fully described in the chapter on paracentesis, Chapter II.

The muscles, the ossicles, etc., of the tympanic cavity have been described in the chapters dealing with their respective surgery. A brief description of the facial nerve and its course through the temporal bone is necessary to understand the technique of the radical operation.

The Facial Nerve: The facial nerve arises from the pons and with the auditory nerve enters the temporal bone at the internal auditory meatus. At first it lies to the inner side of the auditory nerve, and then in a groove above it; filaments connect the two nerves in this region. At the bottom of the internal auditory meatus, the facial nerve enters its separate canal—the aquaeductus Fallopii—and follows the turns of the aquaeductus until it emerges from the skull at the stylo-mastoid foramen. (See Fig. 22 and Fig. 50.)

After emerging from the temporal bone the nerve divides, and passes through the substance of the parotid gland to supply the muscles of the face. The point of emergence of the nerve is very superficial in the newborn and in young children, and may be injured when the primary incision is made.

Its course at first is directed outward toward the hiatus Fallopii; it then bends rather suddenly backward, and runs along the internal or the labyrinthine wall above the fenestra ovalis, and inferiorly to the horizontal semicircular canal. Passing to the posterior tympanic wall below the antral opening, it turns at an angle and passes vertically to the stylo-mastoid foramen.

Within the aqueduct it gives off the tympanic branch to the

stapedius and the chorda tympani nerve; at the hiatus Fallopii it forms a reddish swelling—the geniculate ganglion. Topographically, the facial nerve is in close relation with the fenestra ovalis, at which point it is only separated from the window by a few lines. The depth of the nerve from the surface of the bone in the posterior tympanic and the posterior canal wall is estimated at from 18 to 22 millimeters.

The Indications for the Radical: The indications for the radical operation have been based rather unscientifically upon symptoms and not upon positive diagnosis of disease. This has caused confusion and has obscured the results obtained by means of the radical operation. Hitherto we have promiscuously operated upon chronic mastoiditis, accompanied by persistent otorrhœa, without considering whether the mucous membrane alone was diseased or whether there existed a complication of underlying bone disease; likewise we disregarded the nature of the disease in the bone, i.e. whether it was tubercular or due to pressure necrosis from the ingrowth of epithelium or cholesteatoma. We compared the results obtained in all these conditions and estimated *in toto* the percentages of cases cured, that is, the number of cases in which we succeeded in stopping the otorrhœa; manifestly this is an error. To rectify such errors, before summarizing the indications for the radical operation, a brief review of chronic suppurative otitis media is necessary.

Otitis media suppurativa chronica can be divided pathologically into two classes—the non-dangerous and the dangerous. The one threatens intracranial complications, the other does not, even when of many years' duration. The presence of the dangerous type demands radical operative measures. The diagnosis between these two types of chronic suppuration is possible to a great extent from the otoscopic picture presented.

Differential Diagnosis of Dangerous and Non-dangerous Otitis Media Purulenta Chronica: In a given case of chronic suppurative otitis media, when the perforation is so situated that any part of its margins—at one or other point—encroaches on the surrounding bony wall, especially when such a perforation is situated at the upper and the posterior quadrants of the drum,

then such a chronic suppuration is usually of the dangerous variety. (Figs. 23 to 26.) We classify under this subdivision those cases also in which the perforation is so large—a defect, in fact, that only a small free fragment of the drum remains, or where the entire drum has been destroyed, presenting the characteristic evidence of a freely exposed annulus tympanicus.

Sometimes, in this class of case, the perforation is seen in the posterior superior quadrant, the drum seems to be detached from the annulus tympanicus; again, the picture presented will show the annulus tympanicus partly destroyed—as *Heine* expresses it, "as if bitten away," and covered with granulations.

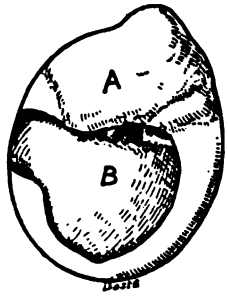

FIG. 23.—Marginal Perforation. Tip of Umbo and Stapedo-Incudal Articulation Visible (Schematic). Dangerous Type. A, Remains of Drum. B, Perforation.

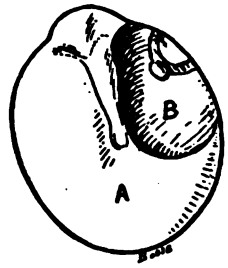

FIG. 24.—Marginal Perforation. Dangerous Type. A, Drum. B, Perforation Exposing Stapes. Incus Absent. (Schematic).

Here we are justified in assuming a diseased condition of the bone, not only in the parts which we see destroyed, but also in the aditus and the antrum. This is especially true when the picture is accompanied by a free flow of pus, which immediately reappears after removal. Such cases, critically examined, will demonstrate the hammer and the incus as well as the lateral (outer) aditus wall to be necrotic. (See Figs. 23 and 24.)

We classify as dangerous, cases where the malleoincudal articulation, either intact or partially or completely destroyed by caries, is visible through a large marginally situated perforation. (Fig. 23.) Portions of the ossicular chain may be absent, (Fig. 24); often only the isolated head of the stapes is visible. The otoscopic picture of a dangerous case is more pronounced when parts of the annulus tympanicus and the lateral (outer) aditus

wall are destroyed by the necrotis process. Additional data to the necrosis of bone are obtainable through the intelligent use of a probe and from a cytological examination of the ear discharge.

Perforations situated well within the limits of *Shrapnell's* membrane point toward an isolated involvement of the malleus head and the aditus walls. (Fig. 25.)

Furthermore, in chronic cases, we interpret, a perforation within the limits of the membrana flaccida, with or without disturbances of the margo-tympanicus, as an expression of disease located in the aditus and more or less limited to its contents.

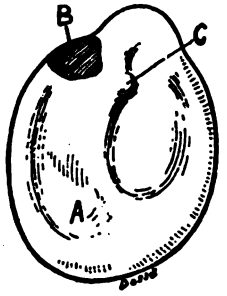

FIG. 25.—Small Marginal Perforation. Dangerous Type. A, Drum. B, Perforation Within Confines of Shrapnell's Membrane. C, Process Brevis. (Schematic).

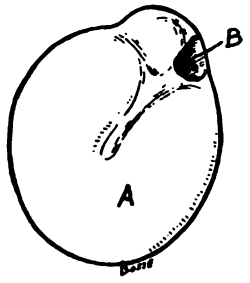

FIG. 26.—Small Perforation (Dangerous Type) Situated Within Limits of Shrapnell's Membrane. A, Drum. B, Perforation. (Schematic).

Finally, we regard perforations situated at the upper pole of the membrana tympani as favoring the ingrowth of epithelium from the derma of the external auditory canal; these eventually develop pseudo, or true cholesteatoma, and when found these lesions are classified with the dangerous cases. (Fig. 26.)

A persistent purulent otorrhœa usually of a distinct fetid odor is present in these cases.

The non-dangerous middle ear suppurations are usually characterized by perforations centrally situated. That is, between the perforation itself and the annulus tympanicus there is presented more or less drum membrane tissue. (See Figs. 27 to 31.) It is in this type of case that we have the kidney-shaped perforations of various sizes, and occasionally even an entire

defect of the drum, with only a slight fringe of its tissue remaining at the annulus tympanicus. (See Figs. 27 and 28.)

Through the perforation, the lining mucous membrane of the tympanic cavity is seen in various stages of inflammatory reac-

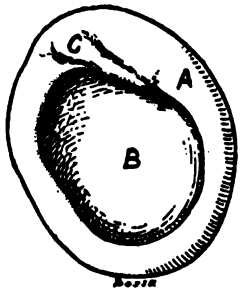

FIG. 27.—Large Non-Dangerous Type of Perforation. A, Remains of Drum. B, Interior of Tympanic Cavity Visible Through Large Perforation. C, Hammer. (Schematic.)

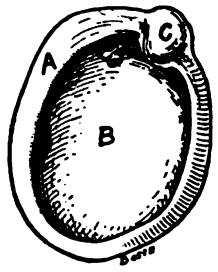

FIG. 28.—Large Non-Dangerous Type of Perforation Showing Large Defect in Drum, B. A, Small Fringe Remaining of Drum. C, Head of Hammer. Stapes Exposed. (Schematic.)

tion. At times, dark, red and swollen; at other times, deviating but slightly from the normal.

The secretions from the mucous membrane may be clear pus, which flakes in washing away, or the character of the otorrhœa

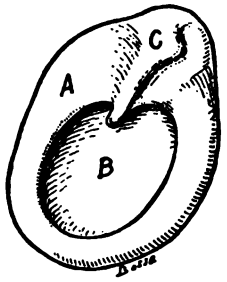

FIG. 29.—Typical Non-Dangerous Perforation. A, Showing Remains of Drum. B, Large Perforation. C, Malleus Head (Schematic).

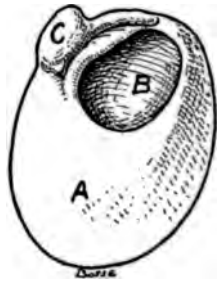

FIG. 30.—Large Non-Marginal Perforation, B, Situated High on the Drum, A. C, Head of Malleus Which is Drawn Out of Natural Position by Adhesions. (Partly Schematic.)

may be muco-purulent. I have had a case of this type under observation for over a year, and the discharge in all this time has never changed its character, nor have I been able to stop it, for reasons designated in the following:

The discharge in these mild non-dangerous cases is usually without fetid odor. Occasionally in cases where the external auditory canal has not been cleansed for some time, some fetor is appreciable, but after the first cleansing the odor ceases. This is especially noticed among children, where experience has taught that the fetor begins earlier; but here it ceases after the first cleansing, and does not recur as long as the canal is kept clean.

The muco-purulent secretions, which produce otorrhœa in these cases, are the products of disease of the mucous membrane of the tympanic cavity or of the Eustachian tube, or they may emanate from both cavity and tube.

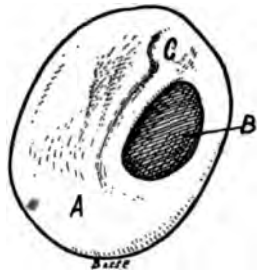

FIG. 31.—Medium Sized Non-Dangerous Type of Perforation. A, Drum. B, Perforation. C, Head of Malleus.

The otoscopic picture where the disease lies in the membrane of the Eustachian tube, usually evidences the perforation in the anterior portion of the drum, and occasionally shows the tympanic orifice of the tube lying free within the limits of the perforation.

Generally speaking, there is no danger of intracranial complications in the class of chronic middle ear suppurations which we have designated, for want of a better name, as "non-dangerous." Intracranial complications may follow when an acute involvement of the mastoid process is superimposed upon the chronic lesion in the tympanic and antral mucus membrane extending to form an acute purulent mastoiditis. On the other hand, cases classified as dangerous are so considered because they eventually tend to produce intracranial or labyrinthine lesions without necessarily first causing an acute mastoiditis.

After reasonable time and effort have been unsuccessfully expended in local treatment, the radical mastoid operation is indicated in all cases of chronic suppurative otitis media which I have classified as dangerous.

Furthermore, the radical mastoid is indicated, when, during the course of a middle ear suppuration, general symptoms of

septic absorption, otherwise unaccounted for, make their appearance.

When extensive exostoses appear in the external auditory canal, concealing the deeper-lying parts and hindering the application of rational local treatment and favoring pus retention, then the radical operation is indicated.

The advent of symptoms from the facial or from the labyrinth, or the first sign of intracranial complications during the course of a chronic middle ear suppuration, demands immediate surgical interference.

The radical mastoid operation is also indicated in acute cases if, after a simple mastoid operation has been performed, fetid pus continues to flow from the middle ear in great quantities, or symptoms of pus retention occur. The flow of pus from the opened mastoid antrum and through the paracentesis opening in the drum is evidently insufficient. Here we resort to the radical operation either to prevent the retained pus from breaking through the anterior tympanic wall and invading the carotid canal; or to prevent the passage of pus along the sides of the Eustachian tube to the neck; or to prevent an infection of the jugular bulb through its roof—the tympanic floor.

From the very onset a middle ear suppuration, especially in scarlet fever or in tuberculosis, may chronically involve all the middle ear spaces. The conditions present at the time of the simple mastoid operation will indicate that the procedure should be converted into the radical operation.

Often a muco-purulent mastoiditis has run a chronic course without giving external evidences of its activity in the form of perforations, *that is, the drum remains intact:* again in cases where the otorrhœa is recurrent, the mastoid process gradually becomes converted into a compact mass of bone through a plastic osteitis. During or after the completion of this process, patients thus afflicted suffer intense pain, neuralgic in character together with aprosexia. Although no actual disease can be detected, either by palpation or by any other means of diagnosis, the distress of these sufferers is such that they readily submit to surgical treatment. In the marked cases of this sort, the radical operation may advantageously be performed for the

evisceration of the compact bone. This seems to afford relief. *H. Knapp* (18).

Finally, the radical mastoid operation is often necessary to permit the removal of impacted foreign bodies and to remove new growths.

Counter Indications: In cases of chronic middle ear suppuration, with a free discharge of pus, it often becomes a difficult question to decide when to resort to major surgical measures. We do not believe that every case of long-standing otorrhœa, even if it fails to yield to local measures should be subjected to radical operation. Otorrhœa is maintained in some cases by caries or bone necrosis, in other cases by a chronic inflammation of the lining mucous membrane of the tympanic cavity; when the disease is limited to the mucous membrane, we hold that the operation is not indicated. *Heine* considers it a technical error to perform the radical mastoid when only the mucous membrane is diseased, and the secretions come partly from the tympanic cavity and partly from the Eustachian tube. The radical operation does not remove the disease from the tube or from all parts of the tympanic cavity; for even after thorough curettement small areas of diseased mucous membrane will remain in the region of the Fallopian canal and stapes. To attempt the removal of these areas entails considerable risk of unpleasant sequelæ, and when, on the other hand, these diseased sections of membrane are left *in situ*, the operation fails to effect a cure of the otorrhœa.

In such cases, even after securing epidermatization upon the healthy bone, the secretions continue to form from the tube and from sections of diseased mucus membrane, upon which no epidermis attaches itself, and the patients continue to have otorrhœa after the operation. These observations are substantiated by *Heine's* experience with this class of cases at *Lucae's* clinic in Berlin. In some of the cases occurring during my earlier operative experience, the radical operation failed in its object because I submitted unsuitable cases to the procedure. The otorrhœa will cease only when the diseased mucous membrane becomes healed throughout its entire extent. Furthermore, the same conditions which counter-indicate the simple mastoid operation hold good regarding the radical. (See Chapter VI.)

When to Operate: The length of time during which conservative local measures may be continued is a matter to be determined separately for each case. *Körner* (3) recommends that the radical be performed as soon as the diagnosis of chronic bone disease is positively made. Others even attempt to cure evident bone necrosis by local measures. We believe, that unless the bone necrosis is very extensive, local measures—ossiculectomy and tympanic curettement—should first be employed; if they fail to afford relief, we proceed to operation.

We operate at once, when an acute exacerbation supervenes, or at the first sign of intralabyrinthine or intracranial involvement. Fever, pressure sensations in the head, distinctly localized, occipital headache, or nystagmus indicates immediate operation.

Facial paralysis coming on during the course of a chronic middle ear suppuration likewise indicates immediate operation, provided no other reason for facial paralysis (*Bell's* palsy) is present. Where tuberculosis is suspected as being at the root of the middle ear trouble, facial paralysis is an especially significant sign, but in these cases, the paralysis is not always a precursor of meningitis.

In necrotic bone lesions, or when cholesteatomatous masses are present in the middle ear spaces, the operation is not immediately necessary. In unhealthy individuals, in ill-nourished children, or in adults sick with some intercurrent disease, the radical operation may be postponed, pending treatment of their general condition. During the interim, however, local care and strict supervision are necessary.

Objects of the Operation: The object of the operation is to relieve the conditions outlined in the indications. The technique is so devised that we are able to locate a small antrum, even in eburnized bone, safely widen it, without injury either to the facial or to the internal ear. We remove purulent foci easily, even when the sinus is far forward, and lay open and bring into view the greatest possible area of diseased bone. Finally we secure healing by covering the interior of the merged tympanic-antral-mastoid cavity, with a layer of epidermis; this renders the cavity permanently open to inspection through the

artificially widened meatus, enabling us to watch for further evidence of necrosis or other signs of recurrence.

Preparation of the Patient: The measures discussed in the chapter on the simple mastoid operation are employed in the preparation of the patient for the radical mastoid; vide Chapter No. VI.

The Bone Operation: The radical operation is divided into two parts: (1), the operation proper, and (2), the plastic flap operation. These may be performed at the same or at different times.

On the Adult: There are two methods of performing this operation, one devised by *Stacke* (19), and the other described by *Zaufal*. The manner in which the end result is obtained constitutes the difference in technique. The *Zaufal* technique, modified by various surgeons, is the procedure most generally employed. Experience has taught us that the *Zaufal* procedure is not sufficiently extensive, in that it does not recommend the removal of all or even the majority of the mastoid cells; hence Americans have modified the procedure by eviscerating all diseased mastoid cells.

The Stacke Procedure: *Stacke* makes his skin incision along the line of the attachment of the concha. The incision is curvilinear, beginning above the linea temporalis, over the fascia of the temporal muscle. A second small incision at right angles to the first runs forward toward the face, underneath the skin, which is pulled toward the front during this manipulation. The first incision is made through skin down to the bone, severing all soft parts, the second incision cuts only fascia and periosteum.

The soft parts are now carefully retracted; the skin and the periosteum are pushed back over the mastoid process and the anterior wound lip is pushed forward. The membranous external auditory canal is now separated from its bony attachments, both posteriorly and above, being cut or torn off as close as possible to the annulus tympanicus. The soft canal is now pulled out from the osseous meatus and pushed over toward the front.

Our operative field now presents between the lips of the retracted soft parts. We see the osseous meatus, and looking down this canal, along its posterior wall, we recognize the membrana tympani, or its remains, and such portions of the ossicular chain as are still intact.

The next step in the procedure is the removal of the malleus, if this is still *in situ*. Grasping it with a thumb forceps, it is loosened from its attachments by a seesaw motion and readily removed. The lateral (outer) aditus wall (pars tympanicus) is now carefully broken away either with a *Kerrison* forceps or, as the European surgeons are still doing, with a small chisel.

The removal of the posterior, osseous meatal wall is now begun. *Stacke* devised a protector to prevent injury to the facial nerve or to the horizontal semicircular canal. During the removal of this posterior meatal wall, the *Stacke* protector is placed in position. The protecting edge of the instrument is introduced under the posterior meatal wall, and the bone removed as the protector is held underneath it. The protector may be dispensed with when the *Kerrison* forceps is used.

The posterior meatal wall is removed working from the external auditory canal backward to the antrum. The intervening bony partition being gradually removed until the tegmen tympani can be traced at an even level with the tegmen antri.

If the incus is still *in situ*, it is now removed. The protector being pushed further toward the antrum, more of the posterior meatal wall is removed. The operative procedure on the bone closes by removing the overhanging cortex, and as much of the mastoid process as is found diseased.

The plastic flap operation, to which we will revert below, now follows.

Advantages of the Stacke Procedure: *Stacke's* procedure presents one absolute advantage over the more popular *Zaufal* technique, *viz.*, it is almost impossible to miss uncapping the mastoid antrum, even when this cavity has been greatly diminished in size through eburnization. Those experienced in the use of the *Zaufal* method, do not consider that the *Stacke* mode of procedure is a surer way to safeguard the facial nerve or the horizontal semicircular canal from injury. On the other hand, the *Stacke* method offers a safer route to the antrum, when the sigmoid sinus is located far forward. Working from the canal backward, the vessel is not so apt to be encountered and perhaps injured as when the *Zaufal* operation is performed. We do not advocate the *Stacke* procedure, but limit its employment

to such cases where anatomical difficulties arise when we try to perform the radical in the other manner; or when an absolute osteosclerosis is present, and in consequence thereof the mastoid antrum is exceedingly small. Even in the latter contingency we have not often been compelled to employ this method.

The Zaufal Operation: The primary incision coincides with that employed in the simple mastoid. It is curvilinear, separated ½ cm. from the auricular attachment, which it parallels in its course, and extends from the upper pole of the auricular attachment to the lower margin of the mastoid tip.

When operating upon a case presenting an acute exacerbation of a chronic otitis media purulenta, if there is great infiltration of the soft parts, or if a subperiosteal abscess is present, then it is advisable to thoroughly clean out the principal foci of the infection first. The parts are then thoroughly washed with antiseptic solution, and the bone operation proper, begins.

The incision should be carried by one sweep through all soft parts down to the bone.

The soft parts are now retracted forward and backward respectively, similar to the method described for the simple mastoid operation.

Operative Field: The operative field now presented is bounded above by the exposed linea temporalis or its continuation backwards; the anterior boundary is made up of the anterior meatal wall, and the posterior boundary is a perpendicular dropped from the linea temporalis to the posterior margin of the mastoid tip. (See Fig. 14 and Fig. 15.)

The posterior wall of the membranous auditory canal is now carefully separated from its bony attachment by a blunt instrument. The membranous canal is then either pushed toward the front and held there by retractors, or is threaded—a procedure in vogue at the Manhattan Eye and Ear Hospital, New York. This consists in introducing a thin strip of gauze, or a piece of sterilized tape into the meatal orifice and pulling it through the tympanic end of the canal by means of a thumb forceps. The tape is then pulled through between the osseous canal and the soft meatal wall; thus threaded the canal is drawn toward the front and given over to the care of an assistant.

We are in the habit of tearing the membranous canal from its osseous attachment; it separates at the juncture of its osseous and its cartilaginous portions. It may, however, be cut close to the annulus tympanicus, as recommended by *Stacke*.

Zaufal and, following his lead, many of the European surgeons (*Heine*), next proceeded to remove the posterior meatal wall, and after this, open into the antrum, gradually working backward over the cortex.

We defer the removal of the posterior wall until the antrum has been opened and the diseased mastoid cells eviscerated.

Following the principles laid down in the previous chapter, we proceed to open the mastoid antrum, leaving a shell of bone as the posterior meatal wall. (See Fig. 16.) When the antrum is large its communication with the tympanic cavity is easily visible. We remove all the overhanging cortex and eviscerate the diseased mastoid cells from the tegmen antri to the mastoid tip and to the inner tablet. The mastoid tip is removed when found to be diseased. In these procedures, we follow the directions given in the previous chapter. The same dangers to the dura and to the sinus are to be apprehended as in the performance of the simple mastoid. Having eviscerated all the diseased areas in the mastoid process, we now proceed to remove the posterior wall of the external osseous meatus; it has been our custom to employ a chisel for this purpose.

We select a point on the meatal wall so high up that were it continued down to its tympanic end, it would cut the bone almost at the junction of the tegmen and the posterior meatal wall. We first make a vertical indentation, and then placing the chisel a little below and behind the indentation, holding it at a very acute angle to the bone surface we remove small, wedge-shaped pieces of bone. As we approach the depth and near the tympanic region we proceed with greater caution. Thus the bridge of bone separating the tympanic cavity from the opened mastoid cavity, is broken through at a point higher in level than that occupied by the facial nerve where it crosses from the posterior meatal wall to run below the horizontal semi-circular canal. *Richard's* curettes are very efficacious in planing down irregularities in this wall; if working in the con-

FIG. 27.—Deep Ear After Tympanic Membrane, Malleus, Incus, and Stapes Have Been Removed. The Stapedius Muscle Divided and Its Tendon Reflected. The Facial Canal Is Open and the Bony Labyrinth Exposed. The Internal Auditory Canal Is Open and Its Contents Displayed. The Superior Portion of the Membranous Labyrinth and the Anterior Portion of the Membranous Cochlea Are Exposed. The Anterior Wall of the External Auditory Canal Has Been Removed. The Tympanic Membrane Is Seen in Its Natural Position. The Eustachian Tube Is Open. The Bony Septum Between the Carotid Canal and the Jugular Fossa Has Been Removed, Exposing the Jugular Bulb. (Modified from Sobotta-Hesse, Anatomy.)

A—Malleus
B—Tympanic Cavity
C—Incus
D—Descending Semicircular Canal
E—Osseous Labyrinth
F—Facial Nerve
G—Cochlear Nerve
H—Vestibular Nerve
I—Auditory Nerve
J—Internal Auditory Canal

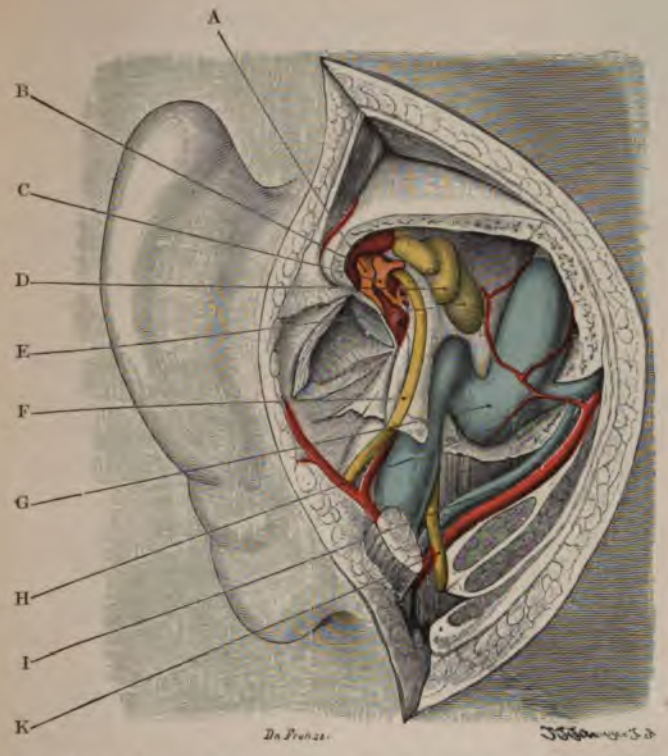

FIG. 22.—Here the Skin Incision is Extended Downward, the Mastoid Tip is Removed, the Digestric Muscle Divided, and the Aditus More Fully Exposed. The Facial Canal is Open and the Bony Covering of the Sinus Removed. The Saccus Endolymphaticus is also Exposed. The Posterior Portion of the Membrana Tympani and the Postero-Superior Osseous Wall of the External Auditory Canal are Removed, the Lining Integument is Slit Open. The Bone Behind the Stylo-mastoid Foramen Has Been Sawn Through, Exposing the Jugular Bulb. (With permission from Bardeleban, Applied Anatomy.)

A—Malleus
B—Tympanic Cavity
C—Incus
D—Posterior Semicircular Canal
E—Saccus Endolymphaticus
F—Facial Nerve
G—Lateral Sinus
H—Mastoid Emissary Vein
I—Occipital Vein
K—Spinal Accessory Vein

verse direction, namely, from within outward, the *Kerrison* forceps is recommended. Whatever instrument is used, the objective sought is avoidance of injury to the facial nerve. The anæsthetist, or an assistant, should be instructed to watch the patient's face during this maneuver, to note any facial twitching. At the first twitch of the face, all efforts at further removal of bone in this situation must be discontinued. We suspect the nearness of the nerve by an increase in the amount of bleeding at the point from which we are removing the bone. Increased bleeding, if from the neighborhood of the facial, comes from a branch of the stylomastoid artery and is to be considered as a warning of proximity to the nerve.

The intervening bony bridge is now broken through, and all overhanging bone is removed toward the front of the upper limits of our cavity; the zygomatic root is cleared away, its cells are exenterated and the bone leveled off up to the level of the tegmen.

It is not sufficient merely to break an opening through from the mastoid antrum to the tympanic cavity; it is necessary that this opening be made as wide as possible; to this end, the lateral aditus wall (outer) is removed. The level of the posterior wall in its lower portions is taken down, until it gradually presents itself only as a gentle rising crest. All irregularities are smoothed away by the sharp curette. Granulations and detritus are now cleared away from the tympanic and the antral cavities until the structures on the mesial (inner) wall come into view. The ossicles, or their remains, with the exception of the stapes, are removed with the granulations.

In a certain number of cases, it is possible to save the anterior portions of the drum membrane intact. *Heine* recommends that this be done, so as eventually to tampon this fragment over the tympanic orifice of the Eustachian tube. We have usually failed in carrying out this recommendation.

When the interior of the cavity has been cleaned, the Eustachian tube next engages our attention. The series of small-sized air cells usually about the tubal orifice are curetted away, and the orifice of the tube is also scraped for the purpose of starting up a reactionary inflammation to seal it. As yet, we

have no satisfactory procedure to accomplish this object. In cleaning out the tympanic cavity, the processus cochleariformis and the tensor tendon should be completely removed. This is usually readily accomplished, but rather easily overlooked. A few sweeps with the sharp curette and the elevation is leveled. If the tendon is still attached to the process, it should be carefully pulled out with a thumb forceps.

The tympanic floor is now lowered, the remains of the annulus tympanicus curetted away, and the floor of the external meatus is planed off until this presents a level contiguous with the floor of the tympanic cavity. When planing down the floor of the external auditory canal to level it with the tympanic floor, the possibility of opening into the glenoid cavity and injuring the maxillary articulation should be remembered. The curette must therefore be used with caution when operating in this locality. In curetting the tympanic cavity, it is a safe rule never to use the curette working posteriorly and upward; such handling of the curette tends to produce dislocation of the stapes.

Toward the front from the oval window, the Fallopian canal enclosing the facial is usually very thin; and very often evidences defects or dehiscences in its bony encasement. The use of the curette here should be marked by great caution to prevent injury to the facial. When the nerve lies free, it is observed as a yellowish-red strand. It is in such cases that paralysis is developed after the operation, due usually to pressure of a tampon or secretions, when the curette did not accidentally injure the nerve. Such paralyses usually disappear in time. The cautious use of the curette or any other instrument is therefore urged when working in this region.

When the operation is undertaken because of cholesteatoma, it is of the utmost importance that every vestige of the cholesteatomatous masses and its matrix be removed. In the earlier otological experience this matrix was permitted to remain, in the hope it would be converted into healthy epidermis. This result was not obtained; on the contrary, it tended to cause recurrences; therefore, we now recommend complete evisceration of the matrix in addition to removal of the cholesteatomatous masses.

FIG. 32.—THE BONE SURGERY OF THE RADICAL MASTOID OPERATION COMPLETED.

A, The Remains of the Zygomatic Root. B, The Aditus Opened and the Ossicles Removed. C, The Tympanic Cavity Rendered Accessible. D, The Remains of the Posterior Osseous External Auditory Canal Wall. E, The Inner Mastoid Table.

PLATE X

When a cholesteatoma is disintegrated, usually as the results of an acute exacerbation of chronic purulency, the removal of the mass is easily accomplished. When, however, the disease is quiescent and the cholesteatoma is small, some portions of the matrix may escape notice. Sometimes the growth is seen in the external auditory canal; in such cases, a careful inspection of the cavity is undertaken before the tampons are applied.

The bone surgery complete, we have an irregular cavity bounded in front by the anterior meatal wall (see Fig. 32), above by the tegmen tympani and the tegmen antri, and continued backward to the posterior margin of the cellular region. Posteriorly the wound cavity is bounded by the remaining shell of the mastoid process. Mesially, the inner tablet of the mastoid process, covering the sinus, the cerebellum, and the cerebrum, are the boundaries in the mastoid region; at the antrum and the tympanic cavity the horizontal semicircular canal is visible, with the facial crest showing directly below it. At the tympanic cavity the structures of the mesial (inner) wall of the tympanic cavity are visible. (See Fig. 32.) The separated posterior membranous canal wall lies in the external auditory meatus attached by its anterior and its inferior walls to the osseous meatus.

At the completion of the bone surgery, the wound cavity should be dried, and its interior minutely inspected. We note the condition of the semicircular canal wall; the pressure effects of the cholesteatoma upon the labyrinthine capsule, or, as the case may be, where extensive caries has involved the facial nerve encasement, we carefully inspect the condition of the facial ridge. We likewise note the condition about the stapes, etc. Information thus gained is of great value in interpreting symptoms which may subsequently develop. I am in accord with *Heine's* views in holding that an opening discovered in the semicircular canal should be left undisturbed until symptoms referable to the lesion make themselves evident; *Jansen* and *Körner* dissent from Heine in this regard. I have repeatedly noted such defects, inflammatory fistulæ, and yet these cases fully recovered without any treatment after complete radical removal of the principal suppurating foci. I deprecate the intro-

duction of any instrument—probes, etc.—into the defect; by such procedures walled-off processes may become diffuse and acute labyrinthitis result.

The Operative Procedure on the Infant and Young Child : The preliminary steps of the operation, the incision into the soft parts and their retraction are performed in the radical with the same precautions and mode of procedure as are laid down for the performance of the simple mastoid in the child. For the discussion of the landmarks guiding the various steps, see previous chapter. The mastoid antrum is first opened in the usual way and as much of its contents eviscerated as are found to be diseased; the boundaries of the operative field are governed by the findings.

The selection of the spot, on the posterior-superior meatal wall (in older children); and on the developing posterior portion of the os tympanicum (in very young infants), where it is safest to break away the bone separating tympanic from antral cavities—is of great importance, because of possible injury to the facial nerve. Fig. 33 shows the relation of the facial nerve in the child.

Our experience teaches us that the nearer we make the connecting passage to the zygomatic root, the safer the procedure will be. The point selected is usually found to be situated directly above the position held by the malleus. The facial nerve at this point has passed into the deeper parts of the petrosal pyramid (Fig. 33), and is, therefore, beyond the reach of the chisel or gouge. (See Figs. 33 and 34.)

The root of the zygoma is now broken down and removed, and the remaining parts of the ossicular chain, with the exception of the stapes, which we keep *in situ*, are taken from the tympanic cavity. The overhang from above is now removed with a biting forceps, and the connecting passage between the antrum and the tympanicus widened and cleared of detritus and pus. The tympanic cavity is next cleared of its purulent or necrotic detritus.

The orifice of the Eustachian tube is wide in infancy and early childhood, and the intervening plate of bone separating the tube from the carotid artery is usually very thin, therefore the possibility of injuring the carotid artery must be kept in

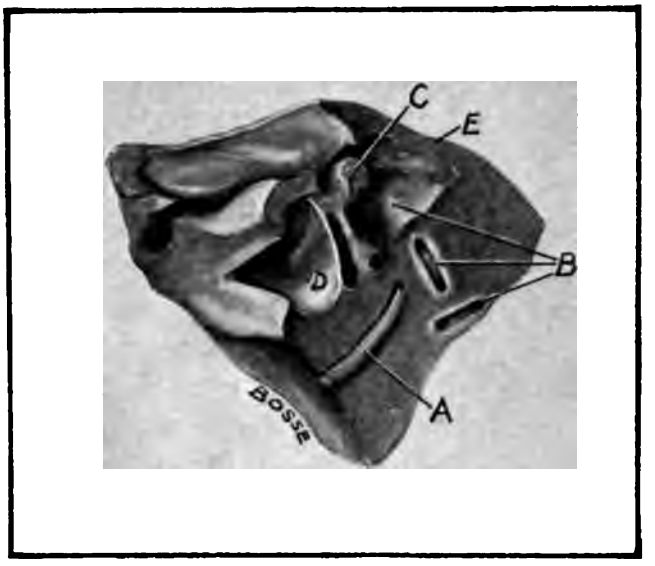

FIG. 33.—A SECTION THROUGH THE PYRAMID (CHILD, 2 YEARS OLD), EXPOSING:

A, The Facial Nerve, and Showing the Relations of the Nerve to B, the Semi-circulars. C, The Malleus. D, The Membrana Tympani. E, The Remains of the Tegmen Tympani. The distance of the Facial Nerve from the Drum is Evident, and the Protection to the Nerve Afforded by the Horizontal Semi-circular Canal is Shown by its Overhanging the Nerve. The Lower Wall of the External Auditory Meatus is Cut Away.

PLATE XI

mind. Small-sized curettes easily enter the tubal opening, and if they are unskillfully handled, the blood-vessel suffers injury. This region should, nevertheless, not be neglected because of timidity in approaching it, for unless this part of the cavity is thoroughly cleansed, healing may not only be delayed but suppuration may recur.

The hypotympanum next engages our attention. It is characteristic of the tympanic floor to be very thin, and often to present bone defects, bringing the jugular bulb and the tympanic mucous membrane into direct contact. This occurs more often in infancy and childhood than we would suppose (23). (See Fig. 19.)

The utmost care is called for in removing granulations, detritus and pus from this region. No sharp instrument should be employed until the surgeon is thoroughly satisfied that the bony floor is intact. We habitually clear away most of the granulations and detritus by means of gauze wipes, and only after careful probing with a blunt-end probe, do we use the curette. Even then, the thinness of this bone calls for gentleness when using the curette.

After the tympanic cavity has been cleared of granulations, we finish the bone surgery by smoothing off all the irregularities, and we lower the spur of bone which remains from opening the antral and the tympanic cavities. Standing out in sharp contrast to the rest of the bone the facial canal usually comes into view, presenting itself hard and white against the surrounding red-colored bone.

Radical Mastoid Operation Modified so as to Retain the Ossicles in Situ: In 1899, *Körner* (3) stated that in certain selected cases, the radical may be so modified that both the membrana tympani and the ossicular chain are kept intact and *in situ*. Generally, this does not bring about good results (*Körner*), but in critically selected cases, t may find useful employment. *Bryant* (59) and *Heath* (58) recently have again advocated this modification of the radical, with the special object of retaining or improving the hearing. Where this procedure is to be employed, it is important that no probes or other instruments be pushed through the membrana tympani. Every care must

FIG. 34.—THE RADICAL MASTOID OPERATION UPON THE CHILD (STEPS SHOWN UP TO THE REMOVAL OF THE OSSICLES).

A, Zygomatic Root. B, Tympanic Cavity Exposed by Removal of Drum, Showing Promontory and Ossicles. C, The Aditus Exposed, and the Separating Wall Between it and the Tympanic Cavity Broken Through at the Zygomatic Root on the Level of the Tegmen. D, Remains of the Posterior Osseous Meatal Wall. E, Inner Mastoid Table. F, Glenoid Fossa. The Lower and Anterior Osseous walls of the External Auditory Canal are Removed so as to Show More Clearly the Anatomical Relations.

PLATE XII

be taken to keep the drum and ossicles untouched during all manipulations.

Following the exposure and the indicated treatment of the antrum and mastoid cavity, after removing any granulations found located within it, *Heath* shapes the aditus so as to fit a cannula into it through which air is blown through the antrum and aditus to the middle ear. Should this passage be unusually long, it is shortened by removing bone from its antral end. A plug is then introduced to keep the passage free from blood and splinters of bone.

The perforation in the membrana tympani next receives attention; it is covered by a tiny wet plug of cotton to keep foreign particles from finding lodgment in the middle ear.

The major part of the posterior meatal wall is now taken away, parts of the upper and the lower canal walls are chiseled off if necessary, so that free access to the membrana tympani is obtained. Polypi or granulations are eviscerated, and where the granulations are present in the tympanic cavity they are removed through the perforation with a small thumb forceps.

In removing bone near the tympanic cavity, the dangers to the facial are to be kept in mind.

The plug at the antral end of the passage through the aditus to the tympanic cavity is now removed, and while the membrana tympani is under close observation, a blast of air is blown through the antral passage.

Occasionally the perforation in the drum is too small to permit egress to the secretions from the tympanic cavity; in such cases the perforation must be enlarged. If the perforation is situated in an unfavorable location (*Heath*), an entirely new opening may be made to facilitate the cleansing of the tympanic cavity of its contained secretions.

A syringe is now attached to the cannula fitted to the antral opening, and the whole tympanic cavity irrigated by some bland antiseptic solution; this fluid is finally expelled by blowing air through the aditus. Plugs are now replaced at the antral end and over the perforation in the drum. Plastic flaps are then cut, modified to meet the conditions presented by the intact drum and the retention *in situ* of a portion of the posterior meatal wall.

FIG. 34.—THE RADICAL MASTOID OPERATION UPON THE CHILD (STEPS SHOWN UP TO THE REMOVAL OF THE OSSICLES).

A, Zygomatic Root. B, Tympanic Cavity Exposed by Removal of Drum, Showing Promontory and Ossicles. C, The Aditus Exposed, and the Separating Wall Between it and the Tympanic Cavity Broken Through at the Zygomatic Root on the Level of the Tegmen. D, Remains of the Posterior Osseous Meatal Wall. E, Inner Mastoid Table. F, Glenoid Fossa. The Lower and Anterior Osseous walls of the External Auditory Canal are Removed so as to Show More Clearly the Anatomical Relations.

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The wound behind the ear is sutured, and the after-treatment is carried on through the cartilaginous meatus, which is enlarged sufficiently to permit the introduction of a drainage tube, about five-eighths of an inch in diameter. *Heath* advises a wet dressing, to be continued in diminishing sizes as long as external dressings are needed.

The operation having rendered the whole tympanic membrane visible, and having kept the tympanic cavity covered, the after-treatment is found to be less painful than under usual circumstances. The day after operation, the dressings and the drainage tube are removed, and the entire cavity cleansed and dried. The patient blows air through the middle ear by the *Valsalva* method, while the drum is under observation. Any discharge thus expelled is wiped away. The cannula is now introduced through the meatal opening and placed in the aditus, and air is blown through the aditus into the tympanic cavity. The drum membrane is watched during this procedure. Any discharge thus expelled is cleaned away. The condition of the hearing is now examined and noted. At each dressing the hearing is examined; *Heath* reports an improvement already apparent at the first dressing.

The cavity is dried, the drum membrane cleansed, and any granulations requiring attention removed; the cavity is covered with an iodoform emulsion, the drainage tube replaced, and the dressings reapplied.

We have had no experience with this method; *Heath* reports having used it in ten cases, in all of which marked improvement in hearing resulted.

It seems to the writer that in specially selected cases, where the disease is limited to the aditus and to the immediate neighborhood of the antrum, and where, moreover, the chronic purulency has not been of too long a duration, that this method might be available. Where extensive necrotic changes are evident at examination of the drum membrane, it would seem that this method hardly met the requirement for radical mastoid surgery. On the other hand, the improvement in hearing is a consideration of great importance, and would at least encourage further efforts along the lines advocated by *Heath*.

Operative Findings: As a rule, unlike the acute cases, we do not find pus in great quantities or under pressure during the radical operation. When a large amount of pus is present it denotes an acute exacerbation of a chronic process or the presence of a broken-down cholesteatoma. Necrosis of bone, usually surrounded by rather hard compact bony areas are the usual findings; these are interspersed with pus tracts running in various directions. Occasionally we find true bone sequestræ lying in a purulent cavity. These sequestræ are of various sizes and shapes, and in their extent oftentimes involve important structures. We have seen the facial nerve imbedded in a sequestra, while an exfoliation of the entire labyrinth has been reported.

Often in chronic cases of long standing, dense, hard, smooth bone is found, with all its landmarks eradicated; the antrum is small, and the bone almost bloodless. This condition, designated osteosclerosis (eburnization), while always observed in connection with long standing middle ear suppurations, has been held to be the result of a chronic suppurative process. The obstacles the dense bone presents to the location of the purulent tracts renders these cases important surgically. The eburnized layers of bone prevent the inflammation from spreading far beyond the antrum and resist its advancement toward the periphery. The purulent tract must then be sought for toward the interior; the operative finding of osteosclerosis is to be regarded as a predisposing factor of intracranial complications. *Heine*, however, reports that he has found osteosclerosis of the mastoid without its being the seat of a purulent process.

Accidents During the Radical Operation: The dangers to the dura and the sinus encountered during the performance of the radical are the same as those met with in the simple mastoid operation. In addition, we are now confronted with possible injury to the horizontal semicircular canal and to the facial nerve. Less common are dangers to the carotid and the jugular bulb, although injury to the latter depends on the anatomical peculiarities of the bony tympanic floor. When the horizontal semicircular canal is opened accidentally, a small bleeding point usually marks the position of the injury. Accidental injury of the semicircular canal is not dangerous, provided no infection

supervenes. When suppuration of the labyrinth occurs, unless it is quickly met by operative procedures meningitis ensues. The accidental opening of the semicircular canal is accompanied, even if the local injury escapes notice, by marked dizziness, especially when the patient is sitting up in bed; this symptom is usually noted as soon as the patient comes out of the anæsthetic. Nausea and vomiting accompanied by horizontal nystagmus, which is most marked when the eyes are turned toward the healthy side, are important clinical symptoms of injury to the semicircular canal. These symptoms usually subside in uncomplicated cases, under rest in the horizontal position; the vomiting disappears first, successively followed by a diminution in the dizziness and the nystagmus. The dizziness will usually disappear in from eight to fourteen days; a slight nystagmus may last much longer. All the symptoms continue for a longer period, if inadvertently, the injured spot on the semicircular receives pressure from a too tightly applied tampon.

The unintentional opening of the labyrinth itself may occur during the cleansing out of the tympanic cavity, from dislocation of the stapes and rupture of its annular ligament. Such opening may accidentally be made in cases where extensive bone destruction is present and exact orientation is impossible or where the removal of detritus and granulations from the tympanum is performed without sufficient illumination. The cochlea under these conditions may inadvertently be opened.

Exact orientation in curetting away tympanic and antral detritus, under proper illumination, will generally avoid this danger, and scrupulous asepsis will lessen the chances of unpleasant sequelæ when the accident happens.

In taking down the posterior meatal wall, the facial nerve is usually endangered, especially when the last small bridge separating the antral from the tympanic cavities is removed. The technique given has been devised with a view to obviate this danger. The clinical symptoms of facial injury is paralysis of the facial muscles, which are supplied by the branches of the facial nerve.

If the nerve is simply cut across, healing has been known to take place after years; where loss of nerve substance has resulted

from careless use of chisel or curette, the paralysis is usually permanent. An artificial anastomosis of the distal end of the nerve, outside of the stylomastoid foramen, either with the hypoglossal (*Körte*, 20) or the spinal accessory (*Gluck*, 21) is a procedure recently devised to cure this condition. These procedures will be discussed later.

When the injury to the facial nerve is external to the Fallopian canal, we note a paralysis of the muscles of the face only. When in addition to the paralysis of the muscles of the face, the muscles of the external ear evidence paralysis, then the injury to the nerve is usually situated within the Fallopian canal, at a point below that at which the chorda tympani leaves the facial. If the facial is injured between the point where the chorda tympani is given off and the nerve to the stapedius, then we will find clinically, in addition to the paralysis described above, an abolition of the sense of taste on the lateral half of the anterior two-thirds of the tongue, and diminution of the salivary secretion on the diseased side. Injury to the facial nerve, between the point of origin of the stapedius nerve and the geniculate ganglion, gives the same symptoms as above, but in addition, there is usually an abnormal acuteness of hearing (*Ross*, 57).

The carotid artery may suffer injury when the curette is carelessly used in the region of the tympanic orifice of the Eustachian tube. The artery runs along the anterior tympanic wall, being separated from the tube by a thin wall.

More frequently the plexus of veins surrounding the carotid is injured. Fear of this accident must not deter the surgeon from carefully cleaning this region of all disease, otherwise the eradication of the purulent process will not be attained.

If the injury to the artery is simply a tear in its outer coat, a sterilized tampon placed over it will usually suffice to control the hemorrhage, If, on the other hand, the entire coat of the artery is completely torn open by the curette, with consequent uncontrollable hemorrhage, the ligation of the internal carotid becomes a necessity, before the bone surgery on the mastoid often can be satisfactorily completed. It is a relatively infrequent occurrence.

The jugular bulb, lying directly beneath the tympanic floor,

is liable to injury from careless use of the curette in cleaning out the tympanic floor—the hypotympanicus. The bony partition is often very thin, presenting dehiscences, which leave the bulb in direct contact with the tympanic mucous membrane. When the bulb is injured by being accidentally opened, a tampon is sufficient to control the bleeding for the time. This tampon is left in place. If uncomplicated by supervening septic thrombi, the case proceeds uneventfully. When complications from the sinus or jugular supervene, they must be met by appropriate procedures.

Faults of Technique: The errors of technique during the radical operation are usually not so much faults in the procedure as faults in incomplete maneuvers. The radical mastoid operation is a major operation, and to be successful must necessarily be extensive. A thorough knowledge of the anatomy of the parts and their inter-relations is conducive to thoroughness. All diseased bone must be removed.

It is a fault of technique not to widely open the aditus ad antrum, to remove all overhang and to lower the posterior meatal wall as much as possible.

The lowering of the posterior meatal wall becomes important during the after-treatment, and overhang interferes with both after-treatment and dressings. In this connection it is well to call to mind a fault of technique to which *Richards* (22) refers, namely, the failure to remove completely the annulus tympanicus. If this is permitted to remain, the process of epidermatization is interfered with, as the course of the epithelium is directed and deviated from the cavity wall into the lumen of the cavity. The underlying annulus acts as a flange, the summit of which projects the epithelium across the anterior wall of the tympanic cavity; this forms a more or less complete epithelial curtain, anterior and nearer the examining eye, than the actual cavity wall. Sometimes the curtain is almost complete; more often it presents a larger or smaller hole in its anterior segment. This is often mistaken for the tympanic tubal orifice. Only the complete breaking down of this curtain, and the removal of the annulus, will result in satisfactory healing.

It is a fault of technique not to thoroughly destroy the tensor

tympani attachment and the processus cochleariformis. I have re-operated upon cases where this fault of technique alone was the reason for the failure to attain recovery. Furthermore, all the conditions discussed under the heading of accidents are usually due to faulty technique. In locating the antrum and working up on the mastoid process, the faults of technique discussed under the heading of the simple mastoid are recalled to the reader's attention. Finally, it is a fault of technique not to follow up to its ultimate end each suppurative tract in the eburnized bone.

The Plastic Flap: After complete removal of all the diseased bone, the final recovery of the patient from the purulent process depends upon complete epidermatization of the bone cavity which has been created.

To accomplish this result, the epithelium to line the cavity is obtained from the membranous external auditory canal; its outgrowth from the canal is furthered and stimulated by the cutting of flaps from the canal and by placing these advantageously in the bone cavity. Added to the epithelium obtained from such flap methods, *Thiersch's* skin grafts are sometimes employed to aid in lining the bone cavity.

A brief description of some of the commoner forms of flaps follows:

Stacke Flap (19): It was *Stacke* who first suggested the employment of flaps to partly fill in and epidermatize the bone cavity. The *Stacke* flap, as somewhat modified by *Jansen*, is made as follows:

The concha is turned forward upon itself. With a narrow scalpel, a puncture is made from behind—that is, from the postauricular wound, through the cartilaginous canal at its upper and posterior margin. As soon as the edge of the knife penetrates, the concha is turned back into its natural place, so that the eye can see and control the knife as it protrudes in the meatal orifice. The performance of this maneuver under full visual control will prevent injury of the anterior meatal wall.

The cut is now carried vertically downward, severing the skin in a line where concha cartilage merges into that of the external auditory canal. The entire procedure must be carefully

done, so that the knife does not leave this line, or a small piece of canal will remain attached to the concha and interfere with the after-treatment; or, on the other hand, the edge of the knife may inadvertently cut into the skin of the post-auricular wound.

Free hemorrhage usually results from severed branches of the post-auricular artery. This is soon under control, however, and the next step in making the flap is undertaken. The second incision is placed at right angles to the one just described. It runs from it, along the posterior and the upper membranous canal walls, horizontally toward the tympanic end of the canal. We are in the habit of using a sharp scissors in making this incision, although the knife is used by many surgeons.

The wound edges made by the first incision (Fig. 35 A-B) are held apart by mouse-toothed forceps, and the scissors are introduced from the meatal side, one blade going through the incision. The scissors are pushed up as high on the wall as the first incision will permit, and the membranous canal spilt open. The result is a large, oblong flap, A, C, D, G, and a very narrow upper one. The large flap is now thinned out, and turned downward and adjusted to the wall of the bone cavity. Experience has shown that this flap usually covers the crest which remains from the removal of the osseous posterior wall and will extend a small distance behind it.

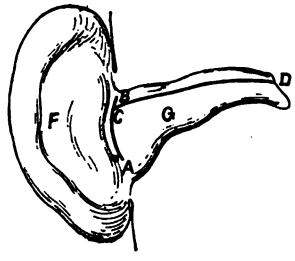

FIG. 35.—The Stacke Flap.

The flap may be sutured into place, although we have found that tamponage properly applied will usually keep it in position.

Tamponage of the wound through the large concheal orifice resulting from this flap next follows, and the post-auricular skin wound may either be closed at once or at such time as the surgeon desires.

The Panse Flap: The *Panse* flap is but a modification of the *Stacke*, just described. Instead of the second incision, which splits the canal open—being situated at the upper part of the canal wall, it is placed in the middle of the posterior wall. (Fig. 36.)

Either the scissors or the knife may be employed to make the incision. We prefer the scissors. The incision, C, D, results in two oblong flaps, which, when thinned out as the conditions present at the operation may demand, are turned upward and downward respectively, and tamponed or sutured into place. We have always secured satisfactory results from the tampon.

Both these flaps give sufficient opening into the surgical cavity, and have the advantage that but little external deformity results from their use. The flaps have been indefinitely modified. Hardly an otological surgeon but has some favorite method of making a flap. To add another modification of the original *Stacke: Jansen* makes the original incision as described for the *Stacke* and the *Panse*. (Fig. 37, A, B.) Instead of placing the horizontal incision at the upper or the middle of the pos-

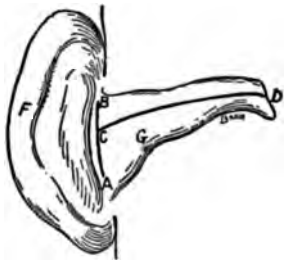

FIG. 36.—The Panse Flap.

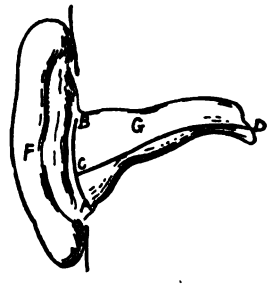

FIG. 37.—Modified Panse.

terior meatal wall, he places the second incision, C, D, as low on the posterior wall as it is possible to place it. This results in a large flap, B, C, D, and a small one, A, C, D. The large flap, after suitable thinning so that it is easily placed in position, is turned up and tamponed or sutured into place. The lower, smaller flap, is turned down against the lower bony wall.

There is some advantage in making this kind of a flap when the disease is situated along the roof of the cavity, and when the mastoid exenteration has not been too extensive.

The findings in the given case must govern the selection of the modification of the flap. There can be no hard or fast rules laid down to guide the operator in all cases. (See Fig. 38.)

The Siebenmann Flap (24): He modified the flap so that he secures a large orifice at the conchal end. (Fig. 39.)

FIG. 38.—Showing a Modified Panse Flap in Position. The Broad Lower One is Shown Turned Down and Held by a Thumb Forceps. The Exposed Area is the Anterior Canal Wall. (Partly Diagrammatic.)

FIG. 41.—A Step in the Formation of the Körner Flap. The Upper Incision Has Been Made, and a Probe is Shown Protruding from the Canal Through the Incision. (Partly Diagrammatic.)

PLATE XIII

His first incision is into the posterior canal wall at about its middle, and he meets this incision at the conchal end by two diverging incisions, reaching into the antihelix. This Y-shaped incision forms three flaps, two oblong ones, C, B, D, and A, B, D, which are turned upward and downward respectively, and the third—an irregular triangular one, C, B, A, which is turned backward. The cartilage is taken out of the triangular flap and the others are thinned to meet requirements. Sutures are generally required to hold the triangular flap in position. The result of this flap gives a large conchal opening. In cases of cholesteatoma or malignant growths, this is an advantage, but we do not often

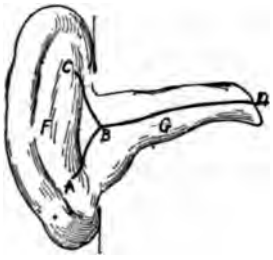

FIG. 39.—The Siebenmann Flap.

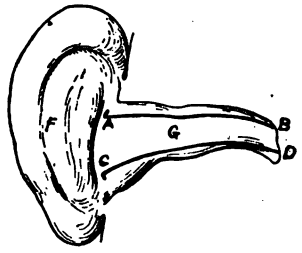

FIG. 40.—The Körner Flap.

find this flap indicated, as the resultant disfigurement is a distinct disadvantage.

The Körner plastic, perhaps the most popular of the various flaps suggested, makes an oblong flap from the posterior of the membranous canal (see Figs. 40 and 41), which is then sutured or tamponed backward and upwards into the surgical cavity. (Fig. 40.) The concha is turned forward and the scalpel introduced from behind, penetrating to the meatal orifice at the convergence of the canal with the concha at its upper extremity. The first incision, made either with knife or scissors, runs (A, B,) from this puncture at the upper posterior part of the canal, along the posterior superior border of the canal to its tympanic extremity. Another—the second incision, C, D, is made parallel with this at the lower posterior border of the posterior membranous canal wall. *Körner* (3) states that the distance between the two incisions should be between ten to twelve millimeters. It is well, however, to make the incisions as far apart

as the conformation of the parts permits, because after thinning out the flap, shrinkage results.

The incisions result is an oblong flap, A, B, C, D. The concha is returned to its normal position and the flap pushed through the conchal orifice. (See also Figs. 41 and 42.)

The excess of tissue under the skin is then carefully pared away, until the flaps present a suitable thickness. The thinned-out flap is now again pushed through the conchal orifice, and placed into the desired position, to be held in place either by suture or tampon. This form of flap is generally sutured into place, although in my own experience the tampon has been found sufficient to keep it in position.

Suture of the post-auricular wound follows. When it is thought desirable to have a large conchal orifice, the result is obtained by carrying the incision further forward on the conchal tissue, thus making the opening wider, when the flap is turned backward. A general rule regarding this flap is that the thinner it is made, the lighter the tampon required to hold it into place. Many reliable authorities have adopted this flap in preference to any other.*

Before proceeding with the discussion of the after-treatment, we will briefly refer to skin transplantation, which is often used in combination with one or other of the plastic flaps to complete epidermatization or to render the after-treatment of shorter duration.

Thiersch Skin Grafts: The grafts are usually taken from the patient's thigh, which is rendered as aseptic as possible, before the procedure begins. The aim should be to secure as large a graft as possible. For this purpose a very sharp razor is employed, and with one steady, slightly sawing motion, the blade held almost flat against the thigh, a large piece of tissue is taken. The piece is secured, and is carefully transferred to a broad, flat spatula, the transference being aided by moistening the blade

* There are many other plastic flap operations detailed in literature. *Berens* (25), *Alt* (26), *Delsaux* (27), *Caboche* (28), *Luc* (29), *Botey* (30), *Brühl* (31), *Passow* (32), *Dench* (33), and others, have written up their particular procedures. It suffices to give only the most important, since the procedure undertaken is largely a matter of choice, and no given procedure presents practical advantages over the older procedures given in the text. (See *Hölscher*, 34.)

FIG. 42.—The Körner Flap Completed, Shown in Situ. The Tongue of Skin is Held in a Forcep. (Partly Diagrammatic.)

PLATE XIV

and spatula with a few drops of normal salt solution. During this maneuver, the graft edges must not be permitted to curl under, and the skin graft must lie flat and even upon the spatula, all air bubbles or excess of blood being removed. The spatula having meanwhile been held in the right hand is now changed to the left and the graft transferred to the mastoid cavity, where, with a sharp needle, a pipette or a thumb forceps pressing upon one edge, it is carefully slid upon the spot which it is destined to cover. Excess of blood and all air bubbles must be carefully removed.

Politzer (35) has recently devised and now uses glass rods to transfer the grafts. These contain on one side a number of small holes. He makes his grafts from six to twenty days after the radical operation. He places the grafts on the rods and by means of a rubber tube and a hand bulb places them in position.

As a general rule, the wound cavity should be as dry as possible before the grafts are applied. *Dench* recommends packing the wound with sterile gauze until the grafts are ready for transplantation.

Air bubbles and blood are best removed from under the graft edges by using a thin glass pipette, which, acting by suction, removes these impediments to successful grafting. After the grafts are in place, they are maintained in position by gauze packing impregnated with aristol, by iodol, or other antiseptic powder.

While skin grafting, if successful, materially hastens the epidermization of the wound cavity, the most valuable result obtained from using grafts is the closure of the tympanic end of the Eustachian tube. To obtain this result, the grafts are placed so as to cover the tubal orifice.

Technical Errors During the Plastic Procedures: When the bone surgery is completed, and the dura or the sinus has accidentally been exposed, it is better to wait some days before the plastic operation is undertaken, although it cannot be considered a technical error to make the flap at once. If serious sequelæ should result from such exposed areas the flap will have to be removed from the diseased parts to render them accessible to further treatment, and then cutaneous tissue is lost for subsequent use.

Körner does not consider it an error to place the flap directly on the exposed sinus. We hold that it is better to wait until healthy granulations have sprung up on the exposed sinus before putting the skin flap into place. Regarding the accidental opening of the cranial cavity, the flaps can safely be tamponed against the dura, provided this has been found healthy when exposed. If found diseased it is safer to wait until healthy granulations are present before making the plastic flap.

It is a technical error to cut a plastic flap when the softer parts are infiltrated as, for example, in cases where the operation was performed for an acute exacerbation of a chronic middle ear suppuration. In such cases, after the bone surgery has been completed, better results are obtained by waiting until the acute infiltration of the soft parts has subsided.

When the flap is cut some days after the bone surgery is finished—any time after the first seven days—then a technical error is made, if the surgeon fails to freshen the granulations upon which the flap is to be placed. Furthermore, the lips of the post-auricular wound should be freshened, and the cutis separated from the underlying tissue for about ¼-inch along the entire extent of the wound lips. Neglect of this often results in failure to procure primary union after suture and, firm adhesion of the flaps.

Failure of strict asepsis, or the slipping of the knife inadvertently into the conchal cartilage may result in perichondritis. Cutting the flaps from the meatal orifice, with the scalpel pointed toward the mastoid wound, may result in accidentally opening an exposed sinus which was uninjured during the operation itself. The author has seen this accident happen.

It is a technical error to place plastic flaps upon unhealthy bone, as the flaps will not become firmly attached.

Choice of the Plastic: The choice of the plastic operation depends on the local conditions present. In infants and young children we prefer the *Panse* flap because the size of the parts renders the procedure the easiest to perform. The edges easily adapt themselves to the bone and the cosmetic after-effects are excellent. With a narrow external membranous canal, one of the modifications of the *Stacke* flap gives the best results. The *Körner* plastic is best suited to a wide canal. In this instance a

larger tongue of skin is obtainable. In cholesteatoma, or where a large meatal opening is desired, the flap should be modified to procure this end. The immediate or the subsequent suturing of the posterior auricular wound must depend upon the conditions present. In children, I have been in the habit of permitting healing by granulations, because the after-treatment is easier to carry out by this means. In adults, the decision is governed by the circumstances of the case. In cholesteatoma, it is safer to keep the wound open and permit healing by granulations.

The kind of plastic operation chosen and the time of the suture of the post-auricular wound have little bearing on the duration of the after-treatment necessary to procure complete healing.

After-treatment: The after-treatment of the radical mastoid begins with the application of the first dressing, immediately after the completion of the plastic steps of the operation, and lasts until healing is complete. The after-treatment of this procedure is as important as the surgical operation, and many a well-performed operation fails in securing the sought-for relief, because the after-treatment has been carried out unintelligently.

The object of the after-treatment is to secure epidermatization of the wound cavity, and the conservation of as much of the hearing faculty as existed before operation; this second object is not always attainable.

The manner of placing the initial tampon in the wound is of great importance. It should be lightly packed, if possible with one strip of gauze, whose end protrudes through the meatal orifice and is lost in the outer dressings. Too tight a tampon not only hinders drainage, but it may prevent the formation of granulations on the bony walls, and often it devitalizes the flaps made at the plastic operation, because of its pressure.

Whether the post-auricular wound shall be sutured immediately after the completion of the bone surgery and the cutting of the flap, or whether this shall be done at some later time remains a question to be decided for each case. The flap may be cut and tamponed into place with or without closing the post-auricular wound. It depends to a great extent upon the conditions found at operation. If we are reasonably sure that all

diseased bone has been removed, and the after-treatment is likely only to consist in proper care of the advancing epidermatization, then suture of the post-auricular wound may at once be undertaken. On the other hand, in cases where the hereditary taint of tuberculosis or syphilis, or very extensive necrotic involvement has been disclosed by operation, the suture of the post-auricular wound had better be postponed to a later period, or dispensed with entirely.

When healing of the post-auricular wound is brought about by granulation, a persistent post-auricular opening sometimes remains. The treatment of these openings will be considered below. In those cases in which the post-auricular wound is sutured immediately, the outside bandage may be removed at the end of ten to twelve days, or as soon as the external wound has healed.

Generally the bandage remains in place one week. The outer dressings are removed to inspect the sutures, and watch for stitch abscesses or signs of local infection. The general rule, not unnecessarily to disturb a healing wound, should be borne in mind.

Fever is usually absent, except in cases which evidence acute exacerbation, in these cases fever may be present on the day following the operation. Toward the end of the week, a rise of a degree may be noted: this is generally due to absorption. The temperature charts herewith (Charts VI and VII) are typical of the fever curve of the uncomplicated post-operative periods following the radical operation.

Fever sometimes denotes local infection, and its presence, when at all persistent, calls for an inspection of the suture line.

It is well to administer a general tonic and give sustaining treatment to undernourished, anemic individuals, and in such cases the patients are permitted to leave their beds as early as possible. We generally limit the rest in bed to the first five days, and increase the diet as rapidly as the general condition of the patient permits.

The first dressing is undertaken at the end of a week or ten days, the second after four days, and thereafter the dressings are changed every second day, unless hypersecretion or other indications call for daily dressings.

At the first dressing after the plastic operation, the cavity is minutely inspected. All its recesses are fully in view and the flaps should be found firmly attached; granulations should have commenced to make their appearance on the uncovered bone areas. The secretions from the wound should be moderate and clean. If *Thiersch* skin grafts have been employed, a distinct odor is often noticeable. This readily disappears at subsequent dressings. The external wound should show healing by primary union. The stitches may be removed as soon as this is established.

The wound is carefully cleaned and redressed. At the second or third dressings, the demarcation of the granulations from the sharp white seam marking the epidermis of the flaps is to be noted. At subsequent dressings, the extension of this line of demarcation over the granulating areas is a sign of successful after-treatment. Exuberant granulations at any part of the wound should be combated by suitable measures.

It was formerly generally held that exuberant granulations were best held in check by applying a tighter tamponade. This has been disproved; in fact, recent publications wherein reports are made on the after-treatment of the radical, show that excellent results are obtained without the employment of any tamponade. *Stein* (36) reports forty successful cases without any tamponade at all.

After-treatment Without Tamponade: This method of treatment was first tried in 1898 by *Zarniko* (37), and later by *Mühlen* (38) and others (36).

The insufflation of boracic acid powder into the wound cavity is all that is necessary in these cases. We have used this method, employing aristol instead of boracic acid, and placing a small drain in the meatal orifice only, and can speak well of the method.

In a recent publication, after eleven years' experience, *Mühlen* (60) reports on the after-treatment of the radical without the use of tampons. In general, his results were very gratifying, and especially in regard to the restoration of functional activity in the operated ear.

Eeman (40) leaves off the tampon after the fifth day, and fills the wound cavity with powdered boracic acid, gradually reducing

the amount of boracic acid employed until only the unepidermatized places are covered with the powder.

The advantage of this procedure is that the changes of dressings are practically painless. It has the recommendation of *Lermoyez* (41), *Delsaux* (27), *Caboche* (28), and others. On the other hand, *Lafite-Dupont* (42), insufflates boracic acid and leaves off the tamponade only after the entire bone cavity is covered with granulations. Other methods have been advocated to limit the granulations. Thus *Warnecke* (43) and *Lautenschläger* (44) employ local application of hot air, to check exuberant granulations and advance epidermatization.

In cases where epidermatization is tardy and no local impediment to its advancement is to be found, *Bondy* (45) obtains good results from the local application of concentrated ethereal solutions of picric acid (1.0 : 10.0). The acid is applied after the parts are thoroughly cleansed. Its disadvantage lies in the intense pain caused by its application. This, however ceases as soon as the ether has evaporated. To hasten evaporation, air is blown into the wound. This treatment is administered every second day, and during the intervals, the wound is kept dry by insufflation of boracic acid or dermatol.

When this plan is adopted the wound secretions rapidly lessen in amount, and exuberant granulations disappear, while the wound surface rapidly becomes covered by epithelium.

In a certain number of cases, after thoroughly cleansing the wound cavity, we have been very successful in checking exuberant granulations by applying orthochlorophenol, followed by absolute alcohol; but in the majority of our cases we simply change the soiled for a clean dressing, and kept the wound surface dry. This has yielded good results. Very often, after epidermatization has taken place on one section of the wound cavity, destruction of the newly formed epidermis takes place, due to the action of the wound secretions from other parts of the cavity. To prevent this, the recommendation of *Brühl* (46), namely, to cover the newly formed epithelium with zinc ointment, deserves mention. We have used lanoline with excellent effect for similar purposes.

Dermatitis of the meatal orifice or surrounding tissue, often

results from faulty asepsis, but occasionally this condition is due to the action of the secretions. Regarding dermatitis, the deleterious effects of iodine should be remembered. We dispense with iodoform after the first dressing, substituting either plain gauze or boracic acid, or aristol insufflations. In children, we entirely dispense with iodoform gauze.

Our own procedure in the local after-treatment of the radical operation is extremely simple. We check any tendency to exuberant granulations by any of the above-named measures; we change the dressings every second day, and unless the secretions are excessive, we wipe the cavity clean with dry or moist wipes —moistened in normal salt solution. The tamponade after the second week is very light; usually in cases progressing satisfactorily we content ourselves with placing a strip of plain gauze in the meatal orifice, and extending it to the antral opening. Previous to the introduction of this tampon, aristol is insufflated. We have already indicated how granulations are kept within bounds.

When the secretions are excessive, we instill hydrogen peroxide, and follow this with 95% alcohol. This usually gives satisfactory results. Where granulations are indolent, general systemic treatment, an outdoor life, and nutritious diet are indicated, together with the local application of balsam of Peru and castor oil in equal parts. One or two applications of the latter are usually sufficient to stimulate indolent granulations.

Results of the After-treatment: The length of time required for healing is different in every case. It is manifestly unfair to compare the results obtained from a procedure which in itself is the same, but which is employed to cure different diseases in the temporal bone. In general, the best results are obtained in from six to eight weeks. Many cases are under treatment for months, and some for years, before final recovery can be pronounced. This is especially the case in undernourished children and in adults debilitated from general disease, and it is an especial feature of tuberculous mastoiditis. The average duration of the after-treatment is between three and four months. Charts VI and VII show the usual temperature curves observed after successful operation. These charts were taken at random and are fairly typical.

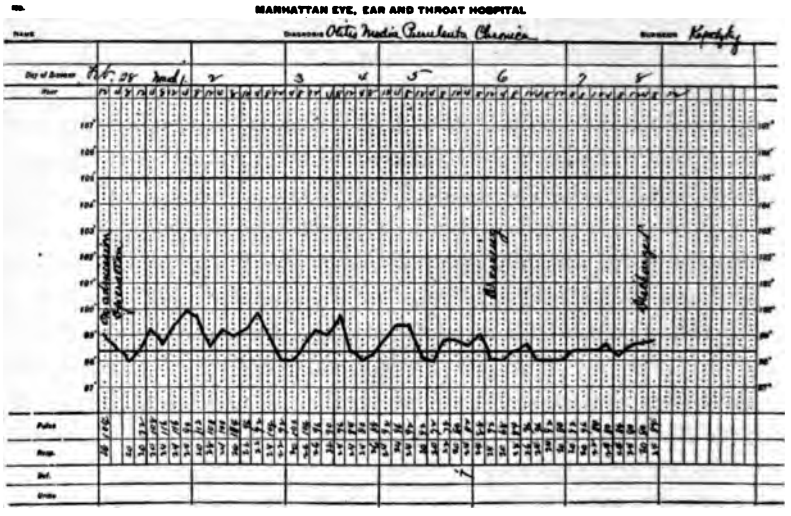

CHART VI.—Typical Temperature Chart of Post-operative Period After Successful Radical Operation. It Shows a Low Febrile Movement.

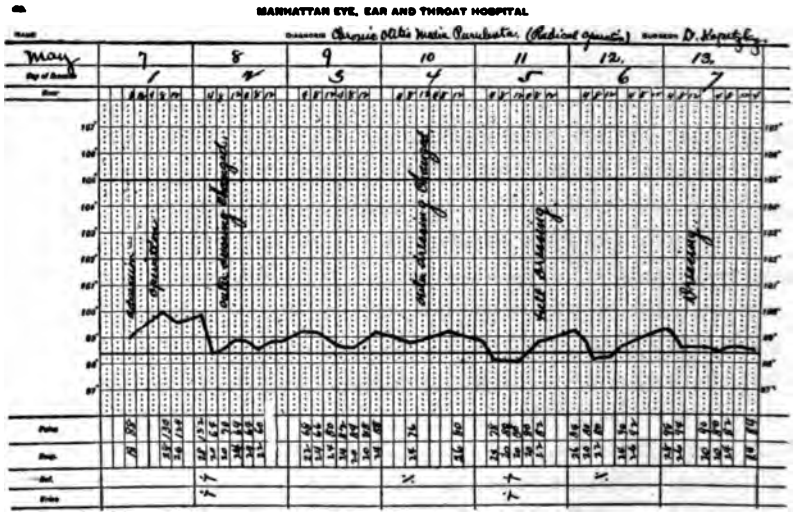

CHART VII.—Typical Temperature Chart of Post-operative Period After Successful Radical Operation.

Unusual Happenings During After-treatment: The determining factors in the success of the after-treatment are to a certain extent the findings at the time of operation. A lesion may thus

be uncovered from which no healing can reasonably be expected. As instances of such findings we cite the following:

Often at operation, a pneumatic mastoid is uncovered. It is then necessary not only to eviscerate all the diseased cells, but also to extend the field of operation to include many healthy ones. Unless all these healthy cells are carefully smoothed off, it later happens, after the epidermis has crept over the bared bone areas and the final contraction of the new tissue has taken place, that irregularities begin to be apparent under the newly formed epidermis. This epidermis sometimes ulcerates over the small, sharp edges which are the remains of intra-cell walls, and sometimes a secondary curettement is necessary to smooth these irregularities away and to prevent a recurrence of the purulent condition in the middle ear spaces.

Furthermore, even when due care is exercised to remove all diseased bone, infected Haversian canals yet persist in parts of the remaining portions of the temporal bone, from which, at times, a fetid secretion exudes. This infection of the Haversian canals may also cause febrile symptoms. More commonly, however, the erosive action of the secretions destroys the advancing epidermis. The condition is combated by frequent changes of dressings, antiseptic powder insufflations, and energetic local treatment by orthochlorophenol and absolute alcohol.

Healing and epidermatization are often delayed by the presence of fairly large necrotic areas, to which the epidermis will not attach itself permanently. Sometimes these areas are not demonstrable macroscopically. They are generally situated on the promontory. The treatment of this condition lies in the removal of the areas of necrosis as far as possible. In cases where the promontory is extensively involved, and the patient is simply suffering from secretions from this area, it is well not to indulge in too extensive a curettement, since such a procedure may inadvertently open the cochlea and lead to unpleasant sequelæ.

Finally, in some cases we are unable to eviscerate all the diseased pneumatic cells, especially those which are grouped about the labyrinth, and which stretch inward toward the pyramid. Furthermore, there are cells grouped about the

tympanic orifice of the Eustachian tube, some of which cannot be reached and removed.

Technical errors made during the operative procedure often cause unusual results during the after-treatment.

The most frequent error of this kind is the insufficient opening of the diseased air spaces. We have referred to these errors of technique above. Summarized briefly they consist in failure to remove all overhang, especially at the outer (lateral) wall of the antrum and tympanic cavity, and in planing down the spur left in removing the posterior osseous meatal wall. There should remain of the latter only enough to cover and protect the facial nerve. Sharp corners, angles or bone irregularities halt epidermatization, and throw the epithelium into folds, and tend to cause retention of secretions during the after-treatment.

Failure to maintain the same aseptic precautions after operation as during the operative procedures, is the cause of many of the accidental findings during the post-operative period. The patient's hair is the most potent origin of the post-operative infections, especially among women.

These local infections halt epidermatization, and if of severe type, often destroy the newly formed epidermis. Infections are manifested clinically by fever, discolored granulations, viscid, sticky secretions, often having a fetid odor, and eczema of the lips of the wound. Often there are present swellings of the neighboring lymph glands, either in the fossa retro-maxillaris, or in the stylo-mastoid region. *Körner* calls attention to swelling of the glands in the latter region, which by pressure upon the facial nerve at its point of emergence from the skull, results in paralysis of the muscles of the face.

This condition is prevented by maintaining asepsis during the entire post-operative period. When infection occurs it is treated by application of antiseptics, by wet dressings, frequently changed, and by the application of astringent solutions, of which nitrate of silver in from 5 to 20% have proved to be the most serviceable.

Perichondritis, a special form of local infection, takes place from faulty technique in making the plastic flaps, and also from subsequent infection. *Heine* has observed perichondritis during

the fourth and the sixth week after the operation. In these cases in addition to the symptoms of local infection, we have swelling of the concha along the infected area, and sometimes pus formation. The patient usually complains of a burning sensation or distinct pain in the affected area. Cosmetic deformities are the usual sequelæ of extensive perichondritis. Finally, a determining factor in inducing unpleasant sequelæ during the after-treatment is to be found in the faulty use of the tampon.

Epidermatization is halted by too tight a tampon. Plastic flaps are sometimes devitalized by pressure, and granulations are thus kept entirely in check or completely retarded in their growth, so that healing is indefinitely delayed.

Summarizing the factors unfavorably influencing the post-operative period, we find that delay in securing healing occurs:

1. Through unfavorable operative findings, from which no recovery is to be expected;

2. Through technical errors during the operation;

3. Through failure to maintain asepsis both during and after the operation; and finally

4. Through misdirected zeal and purposeless after-treatment.

Estimation of Results of the Operation: In a proper estimation of the results of the radical mastoid operation, the disease in the temporal bone for which the operation was performed should enter into consideration. To tabulate the results from a number of operations without considering the diseases for which each was performed is manifestly an error.

The computation of results, obtained from operating on a series of mastoids presenting various pathologic lesions, and having only one symptom—persistent otorrhœa—in common, and from such figures to report percentages of success and failure on the question of cessation or recurrence of the otorrhœa, is an evident fallacy.

A glance at the indications for the operation will reveal the diverse conditions for which it is performed. The operation is performed for cholesteatoma, tuberculosis of the temporal bone, for purulent middle ear suppuration involving only the mucous membrane, as well as for necrosis of bone in suppurating middle ear disease, and to estimate results, each classification of middle

ear disease should be separately considered. The cessation of the otorrhœa is a separate question.

Aside from failures due to faulty technique, we obtain excellent results from the operation when it is undertaken to eviscerate necrotic areas in the aditus and the tympanic cavities, or the mastoid cells. When necrosis involves the promontory or the temporal pyramid, the results are usually bad, and recurrences of the symptoms are common. In the latter class of cases, we may lessen the danger of unpleasant sequelæ by the large drainage opening we make, and the accessibility of the parts to subsequent treatment; but the otorrhœa will persist in the form of wound secretions for an indefinite post-operative period. In such cases it is well, if the diagnosis of the condition can be made before operation, to inform both patients and friends that the operation is not undertaken to cure the "running ear," but to render subsequent treatment easier.

Otorrhœa, occurring in cases which present necrosis of bone in the tympanic or the antral cavities and in the mastoid process —usually ceases promptly upon the completion of epidermatization. The most brilliant results are obtained in this class of cases. In tuberculosis of the temporal bone, if the disease has been radically eviscerated, both recovery from the otorrhœa and the prevention of recurrence are good. The rapidity of healing will depend upon the general condition of the patient and the extent of other tuberculous foci. In these latter cases recovery is usually slow.

In cholesteatoma of the middle ear and of the mastoid, the recovery depends upon the area involved and the thoroughness with which all traces of the growth are eradicated. The otorrhœa usually ceases promptly upon the completion of epidermatization.

Recurrences of the cholesteatoma are, however often observed, although there are cases reported where cure has resulted from the primary operation. In any event, the danger of a cholesteatomatous mass developing to large proportions is lessened after a radical has been performed, as then the cavity is in sight, and can be kept under observation at stated intervals.

In cases where the radical operation is performed for a per-

sistent purulent otorrhœa, the symptom of a chronic inflammation of the mucous membrane of the middle ear often associated with a similar condition of the mucous membrane of the Eustachian tube, the results of the operation are generally bad. The otorrhœa is not influenced by the operation, and because it is impossible to remove all the diseased mucous membrane from the tympanic cavity—especially around the labyrinthine windows and the Eustachian tube—the membrane re-forms, and during its regeneration, it becomes diseased by contiguity from the diseased areas in the Eustachian tube or about the labyrinthine windows. The otorrhœa, which is the external evidence of the secretions from the diseased mucous membrane, naturally continues.

In such cases, *Heine* goes so far as to declare it a technical error to operate at all. We hold, however that the diseased membrane is more accessible to local treatment after the radical procedure is performed. Furthermore, both patient and his friends should be made distinctly to understand that the operation is not undertaken to cure the otorrhœa, but rather to render the middle ear more accessible to treatment.

On the Hearing: The radical operation plays but a small rôle in either favorably or unfavorably influencing hearing. The amount of hearing retained after operation depends to a great extent upon the amount of hearing previously possessed by the patient.

In cases where deafness is due to ankylosis of the conducting apparatus, the hearing faculty may be keener after the operation than before. An increase in the amount of deafness after operation is usually observed in cases where the ossicular chain was functionally active before operation.

Where adhesive bands form about the stapes, impairment of hearing is greater after operation. In osteosclerosis, deafness is often increased after operation; this is said to be due to the shock the labyrinth receives from the unavoidable use of the hammer and chisel during the operation. In these cases a certain proportion show an improvement in hearing after a lapse of time. In specially selected cases the *Heath* method of procedure seems favorably to influence the hearing (*Heath*, 58).

Results of the Radical: Of 200 cases operated in *Schwartze's* clinic, *Grünert* (47) reports that 99 were cured. He designates 37 as not healed but "dry"; these occasionally demonstrated crusts and uncovered arid unepidermatized areas. Among these he cites the cases in which he does not consider sufficient time has elapsed to warrant any conclusions as to the results obtained; he also includes a large number of cholesteatoma cases. He reports 34 cases unhealed and 11 deaths (5.5%). Of these deaths, 10 died of intracranial complications, symptoms of which were already evident before the radical was undertaken. One died of meningitis during the post-operative period, and 19 cases were unaffected one way or the other by the operation. In 71 cases, the hearing was improved 39 times; it was found to be worse after operation 4 times. He reports, that where the labyrinth was intact, the hearing usually improved after operation.

Stacke (19) reports 100 cases with 94 cures; among the 6 unfavorable cases there were 3 deaths of complications which had no connection with the operation. One case was not cured. The other 2 cases were unfinished at time of his report. He reports that the hearing was improved in 31 cases; it was worse in 6 cases, although only in 3 of these was it very much worse, and in 49 cases it remained unchanged. In 14 cases no record of the hearing was made.

Trautmann (48), and also *Müller* (49), have obtained about 70% of cures. The former reports 71 cases in which 24 times there was no noticeable difference in the hearing (whisper voice test) after operation. Improvement was noted in 25 cases, and 2 were not examined in this regard. The hearing was found to be worse after operation 20 times. According to *Körner* (3), the hearing is generally improved if the labyrinth remains intact, while *Politzer* (50), and also *Hammerschlag* (51) find that the operation does not influence the hearing either for better or for worse.

Grossmann (52), reports 212 radical operations from the service of my former chief, *Professor Lucae.* He finds the hearing improved in 93 cases (43.8%). Fifty-one cases (24.1%) showed the hearing to be worse after the operation, and 68 cases, or

32.1%, demonstrated no difference in the hearing after the operation.

Grossmann states that where the hearing is very good at the time of operation, it is apt to deteriorate after the radical. The changes in hearing were only noticeable a considerable time after operation.

Finally, the hearing is worse after operation where membranous folds are formed, during the post-operative period, shutting off the mesial tympanic wall from the meatal orifice. This membrane is a mechanical obstruction to the transference of sound waves to the labyrinth.

After recovery is complete, it sometimes happens after the lapse of considerable time, that the epidermis of the opened air spaces of the middle ear becomes diseased. At one or another place the epidermis becomes loose and raises off from the underlying tissue. In this condition, the loosened epidermis easily breaks down because of the poor blood supply in the underlying connective tissue. Crust formations appear, which, when lifted, often reveal pus pockets underneath. Occasionally regional glands become swollen and the patient may exhibit a low febrile movement. This condition must not be confounded with a recurrence of the chronic middle ear suppuration, since recurrence of disease of the bone in uncomplicated cases is a comparatively rare occurrence.

The treatment of this condition consists in carefully removing all the crusts, soaking them off with glycerine, followed by the local administration of weak silver solution, and powder insufflations.

Procedures to Close Persistent Post-auricular Openings: Occasionally, after the performance of the radical operation, a persistent post-auricular opening is desired because of the conditions found in the middle ear and in the mastoid. In these cases the post-auricular wound is not sutured, and the middle ear cavities are treated during the post-operative period from the open post-auricular wound. The healing takes place by granulation from the depth of the wound toward the surface. In the simple operation, healing takes place in a similar manner.

It occasionally happens that the granulations having reached

a certain development remain stationary, and the skin around the opening joins the granulation level and results in an undesired persistent opening.

Again, the retro-auricular opening has a value of its own. Often it is the deliberate result of the surgeon's efforts. Those holding with *Passow*, that the primary suture of the post-auricular wound often defeats the object of the radical operation, endeavor to keep the post-auricular wound open, in order to prevent the possibility of recurrence, and to facilitate the after-treatment. The indications pointing toward the maintenance of a persistent retro-auricular opening may be summarized as follows:

1. Where the case has demonstrated the presence of a large cholesteatoma in the temporal bone, the persistent opening permits an easier and more thorough inspection of the middle ear cavities, and facilitates the removal of cholesteatomatous deposits should such reappear during the post-operative period.

2. When there has been great loss of bone substance, the open wound affords a better opportunity of watching the course of healing. It may be closed at any subsequent opportune time.

To Form a Persistent Post-auricular Opening: To create a persistent post-auricular opening, the plastic devised by *Kretchman* (53) deserves mention.

The plastic flap is made from the membranous canal, according to the procedure advocated by *Panse*, and then in addition, a skin flap is made from the integument of the post-auricular wound.

The latter is cut from the derma of the posterior edge of the wound and is drawn into the bone cavity. An incision is made, curvilinear in form, from the upper pole of the original mastoid incision paralleling it in a general way, but sweeping backward to the hair line, and being brought forward below to the original mastoid incision. A second incision connects the original mastoid incision with the incision just described. This makes two skin flaps which are loosened from their underlying attachment and placed in the bone cavity.

Furthermore, if it is desired to use skin grafts to cover the exposed bone cavity and still maintain a persistent post-auricular

opening, *Oppenheimer* (54) recommends the use of pedunculated grafts of various sorts and the employment of tamponade directly through the opening.

Disadvantages of Post-auricular Opening: The great disadvantage of maintaining the persistent post-auricular opening lies in the necessity for frequent changes of the dressings and of the tampon; the latter is usually accompanied by pain.

The time when it is deemed advisable to close the retro-auricular wound depends upon the condition in each case. The amount of diseased tissue remaining in the bone cavity and the degree of cicatrization of the cavity will govern our judgment. Generally, I agree with *Oppenheimer* in holding that it is safer to err on the side of safety and permit the opening to remain open longer than is necessary, than to close it prematurely.

The opening should never be closed as long as any suppuration persists; and the plastic operation to close the opening should only be performed when careful examination has revealed the cavity to be dry and completely covered with firm, dry, hard, and fully adherent epithelium, with no evidences of eczematous infiltration or excessive desquamation.

To Close Persistent Post-auricular Openings: Whether the post-auricular opening is the result of failure to secure primary healing or is the after-effect of healing by granulations, or the result of a deliberate action of the surgeon, the method of closing it is essentially the same.

Various procedures have been devised, the choice of which depends upon the size of the opening, its site and the condition of the diseased ear.

Among the commoner methods in use to close persistent post-auricular openings, are those devised by *Passow-Trautmann* (55) and by *Mosetig-Moorhof* (56). These methods exemplify the essentials of the procedures. Frequently the conditions present do not permit the carrying out of these typical steps, and the procedure must be modified to meet the requirements of the case under observation. Integumentary flaps are then taken from the most available locality and transplaced to cover the opening.

The Trautmann Procedure: The neighboring parts are thor-

oughly cleansed with soap and water and antiseptic solutions. The mastoid wound cavity is also carefully cleansed, and its interior protected by introducing a piece of sterile gauze into the wound interior. At the upper and the lower margins we make an incision running toward the interior 2 mm. in depth.

The opening is then circumscribed by two incisions, one along the posterior wound margin and one along the anterior wound margin—separated from the opening's edge at its widest part, about 4 mm. (See Fig. 43.)

The posterior incision must penetrate through the periosteum down to the bone. The anterior incision penetrates to the perichondrium. This results in two crescentic flaps. The posterior one is separated from the underlying parts by means of a blunt elevator and the anterior crescent is usually easily loosened by the knife handle. To prevent spanning of the parts, it is sometimes found advisable to loosen the soft parts over the mastoid process for some distance backward.

The two crescentic flaps are now inverted and placed into position, so as to cover the opening. The sutures are now introduced.

Trautmann advocates four sutures, in both the anterior and the posterior flaps. These are inserted by the use of two threads in each flap. (See Fig. 44.)

The needle containing catgut ligature is introduced from above downward, near the wound edge, as shown in Fig. 44. This needle is drawn off. This leaves the suture in place, making threads A and B. A second suture is introduced somewhere lower making threads C and D. The same procedure is applied to the anterior flap. (Fig. 44.)

The sutures clamped for identification are now drawn together, and those of the anterior and the posterior flaps, lettered similarly, are tied together. Thus threads B of both anterior and posterior flaps, being held by assistants, their other ends constituting threads A, are tied together. (See Fig. 45.) Then the threads B are tied together and knotted. Threads C and D on each side respectively being one suture, the lower ends (threads D) are held by assistants while C is tied, after which the threads lettered D are tied and knotted. (See Fig. 45.)

FIG. 43.

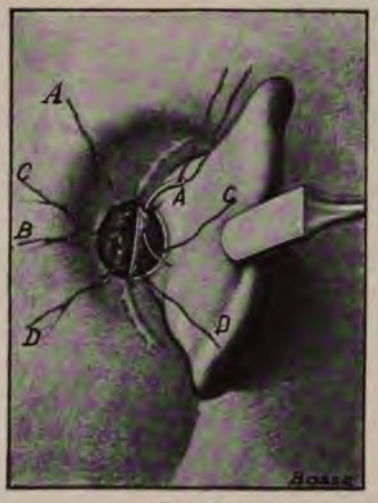

FIG. 44.

FIG. 43.—A Step in Closing a Persistent Post-auricular Opening. (Trautmann Method.) The Dark Line Shows the Two Incisions Placed so as to Make the Two Crescentic Flaps.

FIG. 44.—Same as Fig. 43. The Two Crescentic Flaps Have Been Turned and Two Sutures Passed Through Each of Them. A-B and C-D are Passed in the Posterior Flap, while the Needle is Shown Putting the Last Suture in Place on the Anterior Flap. (Trautmann Method.)

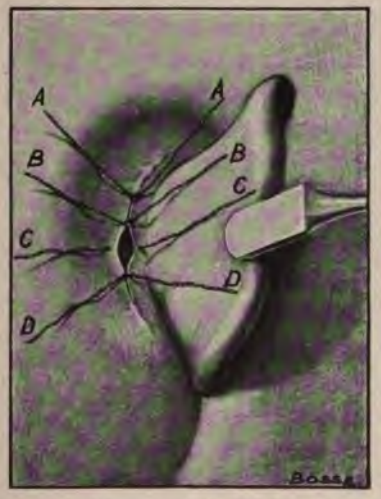

FIG. 45.—Final Step in the Closure of Post-auricular Opening, Showing the Threads Similarly Lettered Being Knotted, to Bring the Parts Together. (Trautmann's Method.)

PLATE XV

Finally, the skin over this denuded area is sutured with fine silk and the wound surface is covered by external dressings and a retaining bandage applied.

This system of suture is very firm and obliterates the opening effectively.

The Mosetig-Moorhof Procedure: While this procedure is simpler, and gives good results in selected cases, it does not result in as firm a closure of the opening as does the one just described. It covers the opening, turning epithelium toward the wound cavity, but unless the cavity is rather small, it has in my hands tended to break down. The skin is not always easily lifted, and sometimes a puckering at the turning point of the tongue of skin results.

By this method a tongue-shaped flap of integument is loosened from the neighboring parts, and so cut that its tegumentary flap is sufficient to cover the opening. (Fig. 46.)

The flap is usually cut from tissue below the opening, but according to the conditions present it may be taken from either in front, above or behind the opening.

The base of the flap, that is, the part whereon it hinges upon being turned, is always nearest the opening, and from this hinge as a base the loop of tissue is cut.

When making the flap from below the opening, a skin flap is cut by a U-shaped incision (Fig. 46), embracing an area of tissue larger than the area to be covered. This first incision only penetrates through the epidermis. A second incision is carried around outside of this first one, paralleling it, but penetrating deeply to the underlying fascia.

The epidermis between these two incisions—a strip of a few lines in width—is entirely removed. The skin flap is then loosened from the underlying tissue, except at its base near the auricular opening.

The rim of the auricular opening next receives attention. An incision is carried around its periphery, except at the point nearest the base of the flap tongue. The incised tissue is undermined with the scalpel along its entire circumference. See Fig. 47.

The tongue-shaped skin flap is now turned upward, so that the epidermal side is turned inward toward the wound cavity.

The rim of this tongue-flap is carefully pushed under the undermined and loosened rim of the auricular opening and held in place by four fine catgut ligatures. (Fig. 48.)

The procedure closes with the suture of the skin wound below the plastic flap. (Fig. 49.) If the denuded area is large, the transplantation of *Thiersch* grafts may be necessary to complete the procedure. Retention dressings are applied and held in place by a suitable bandage.

We have succeeded by the following procedure in effectually closing persistent retro-auricular opening.

The first incision is made along the scar line of the original mastoid incision, skirting in its course the anterior edge of the persisting opening. The rear lip of the wound thus formed contains the scar tissue from the original mastoid incision. With a sharp scissors all this scar tissue is removed. A short second incision meets this at the retro-auricular opening beginning above, where the first incision skirts it, and extending around the opening behind until it again impinges on the first incision below the opening. This incision is carried down to the bone. A third incision begins at the upper pole of the original mastoid incision, it is carried downward in a curvilinear sweep, taking in enough tissue to cover the opening, and as the lower extremity of the primary incision is approached, it meets this at its lowest extremity. This results in a large crescentic flap, which is separated from the underlying tissue and slipped over, across the retro-auricular opening. Sutures are placed along its anterior border to the skin of the anterior lip of the original incision.

At the posterior edge of this flap, deep sutures are introduced along its edge into the neighboring tissue. This leaves quite a denuded surface, which gradually becomes covered over as the epidermis advances from the surrounding edges.

Antiseptic dressings are placed over it and a retention bandage applied. This procedure is recommended only where the retro-auricular opening is very large. It does not present an epidermized surface toward the tympanic cavity, and, therefore, should be employed only where the plastic on the canal has given a large meatal opening, so that the granulation of the surface in the interior can be watched and treated.

FIG. 46.

FIG. 47.

FIG. 48.

FIG. 49.

46.—A U-shaped Flap Cut from the Tissue Below the Post-auricular Opening. (Mosetig-Moorhof Method.)

47.—Same as Fig. 46. Knife Shown Making Incision About the Periphery of the Post-auricular Opening. (Mosetig-Moorhof Method.)

48.—Same as Fig. 47. The Flap Turned Upward and Sutured into Position Over the Opening. (Mosetig-Moorhof Method.)

49.—The Completion of the Mosetig-Moorhof Procedure, by Suturing the Denuded Area Below the Flap.

PLATE XVI

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CHAPTER VIII

THE SURGERY OF THE LABYRINTH

Historical—Anatomical—Surgical Landmarks—Indications for the Surgical Opening of the Labyrinth—Contra-indications—Operation on the Labyrinth—Points of Technique—Operative Findings—Value of the Operation—After-treatment—Results of the Operation.

Historical: The opening of the labyrinth, when it is the seat of suppuration, is the suggestion of *Jansen* (1), 1895; since that time many otologists have reported cases in which they tried the procedure. Among the earlier publications are those of *Lucae*, *Kummel*, *Dundas Grant*, *Bruger*, *Bourguet*, and *Frederick* (2). Lately, in June, 1907, a new and more perfect technique was presented to the American Laryngological, Rhinological and Otological Society by *John D. Richards* (3). It is as yet too early to place even a relative value on the various procedures, as our experience is not sufficiently extensive with any of them.

Anatomical: The bony labyrinth, located in the petrosa of the temporal bone, consists of a central chamber or opening, designated the vestibule, and various tortuous channels which connect with it. (See Fig. 50.) The vestibule is oval in shape, its vertical being greater than its transverse diameter.

The outer (lateral) wall of the labyrinth is the mesial wall of the tympanic cavity and presents a kidney-shaped orifice, the fenestra ovalis, in which the footplate of the stapes and its annular ligament are situated.

Its inner, or mesial wall, presents two depressions or fossæ between which the crista vestibuli is located. The anterior fossa, designated the recessus sphericus, is occupied by the saccule. The more posterior of these fossæ lodges the utricle, and is designated the recessus ellipticus.

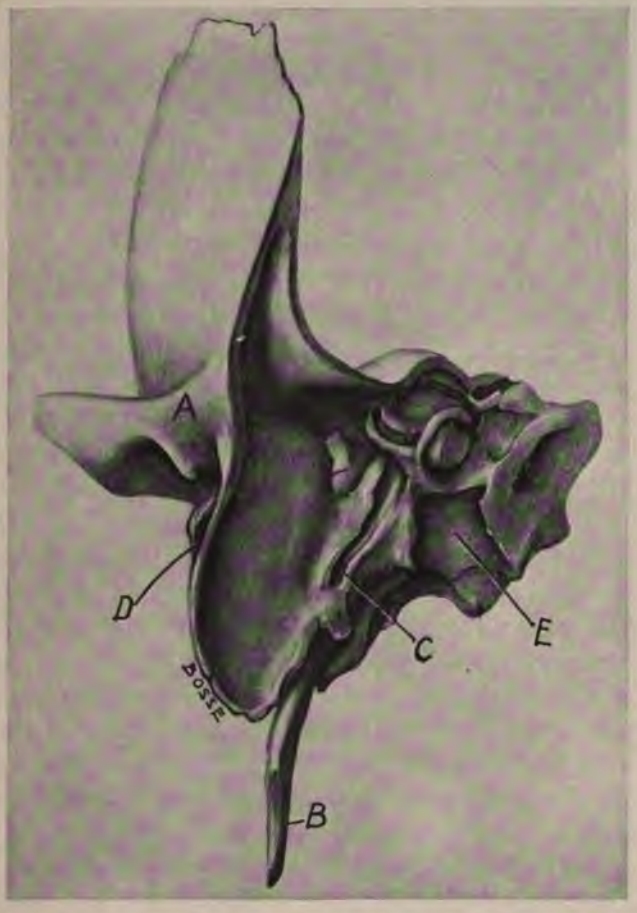

FIG. 50.—SECTION THROUGH THE TEMPORAL BONE AT THE PLANE OF THE FALLOPIAN CANAL. THE MASTOID CELLS HAVE BEEN ERADICATED, LEAVING ONLY A SHELL. THE SEMICIRCULARS ARE OPENED, AND THE RELATIONS BETWEEN THE FACIAL NERVE, SEMICIRCULARS AND BETWEEN THE LATTER AND THE INTERNAL AUDITORY MEATUS IS SHOWN.

A, Zygomatic Root. B, Styloid Process. C, Open Fallopian Canal. D, A Bristle Passed Through the External Auditory Meatus into the Tympanic Cavity. E, Part of the Canal for the Carotid.

PLATE XVII

Posteriorly, the vestibule presents five openings which lead into the three semicircular canals. The superior and the posterior semicirculars have each a separate opening, and one in common; there are two openings for the external semicircular canal. Anteriorly, the cochlea opens into the vestibule. Inferiorly, and close to the border of the recessus ellipticus, a small orifice is presented, which is the opening of the aquaeductus vestibuli.

In the enclosed labyrinthine space there is a tender membranous labyrinth—an endolymphatic space. The area lying between the endolymphatic space and the bony covering is termed the perilymphatic space. The endolymphatic space macroscopically is entirely enclosed, and contains a fluid known as the endolymph. The perilymphatic space communicates through the cochlear aqueduct with the subarachnoidal spaces of the posterior cranial fossa, and contains cerebrospinal fluid.

The internal ear lies in the temporal bone in a direction running from behind above, and laterally (outwardly) toward the front below and inward. (Fig. 50.)

Semicircular Canals: The semicircular canals are three in number, and are so disposed that the plane of each is perpendicular to that of the other two. They are designated the superior, the posterior (lateral) and the external (horizontal). The superior semicircular canal, as its name implies, is the uppermost or highest situated canal. It raises a protuberance on the cranial surface of the temporal pyramid, and is placed vertically in space. The posterior semicircular canal, having its origin in common with the superior, is also placed vertically to the long axis of the petrous portion of the temporal bone, while the external or horizontal semicircular canal is placed in a horizontal plane. The latter forms a protuberance on the inner (mesial) antral wall, and is in relation below with the facial canal. At their points of origin, near the vestibule, they all present enlargements, which are designated "ampullæ." The horizontal has its ampulla at its outer extremity, and the posterior and the superior canals present their ampullæ at their conjoined extremities.

The Cochlea: As stated above, the entrance to the cochlea is situated at the anterior and inferior walls of the vestibule.

The cochlea is an osseous tube, coiled upon itself two and a half times; the axis of this spiral is designated the "modiolus." The modiolus is a pyramidal-shaped portion of bone, around which the turns of the cochlea are placed. The cochlear pyramid presents an apex and a base, both of which are structurally very weak. The base is somewhat excavated (*Politzer*). The outer casing of the modiolus is brittle bone; the core is porous, made so by canals running from its base to its apex; these canals transmit various structures. (*Richards.*)

The interior of the turns of the cochlea presents a very thin septum of bone, extending into the lumen of the tube and dividing it into two apartments. This septal-separating ridge, springing from the modiolus, is called the lamina spiralis. It is made up of two bony plates which do not completely extend across the lumen of the cochlear turn, but extend only to about its center, the intervening space being bridged by a membranous septum. The membranous septum is known as the lamina spiralis membranacea.*

Surgical Landmarks: The surgical guides for operating upon the labyrinth are to be sought upon the inner surface of the mastoid cavity after the completion of the radical mastoid operation.

To obtain a better view of the field of operation, the spur remaining from the removal of the posterior meatal wall should be shaved down as closely as possible to the facial encasement. The floor of the external auditory meatus should likewise be lowered at the point where it normally rises, so that an operative field as wide as possible is laid open for inspection. The exenteration of bony tissue is carried out to its utmost between the knee of the sinus and the outer surface of the middle cranial fossa, so as to give additional working room.

On the internal wall of the cavity thus presented, we note a ridge of hard, white bone, marking the protuberance caused by the horizontal semicircular canal. Backward from this, and extending slightly upward, is the so-called surgical "solid angle."

* It is not deemed necessary to give more than this sketch of the anatomy of the internal ear, as this suffices for the comprehension of the surgical procedures on the labyrinth.

The facial nerve in its encasement is seen extending from under the spur left from the posterior meatal wall, turning toward the tympanic cavity, and extending across its mesial, or internal wall, just below the horizontal semicircular, and above the oval window.

The greatest difficulty in the performance of surgical procedures on the labyrinth is avoidance of the facial nerve. *Bourguet* (4), whose excellent work establishes the anatomical relations of the facial nerve, gives the following important details:

The horizontal portion of the facial nerve is fixed definitely at the oval window and at the horizontal semicircular canal. The nerve follows its course between these two anatomical landmarks, which are comparatively easy to recognize after the middle ear spaces have been fully exposed by means of the radical mastoid operation. *Bourguet* made measurements to establish the distance of the nerve from the upper margin of the fenestra ovalis, and finds that the intervening space is about 3 mm.; this distance is constant.

He further finds that the distance between the facial nerve and forward bend of the horizontal semicircular canal varies. *Bourguet* distinguishes a "Forme droite," or right-angled form, and a "Forme oblique," or an oblique form of the vestibule. The right-angled type was present in 12% of his examinations, the oblique arrangement in 88%. With the last-named type, the author found what he terms a "Situation basse," or a deeply situated forward bend of the horizontal semicircular; that is, the semicircular did not present itself above the nerve, but somewhat behind it. This occurred in three specimens examined. In the right-angled type, the semicircular canal was usually found at a higher level than the position occupied by the nerve, the distance between the nerve and the semicircular canal equaling from 1½ mm. at the beginning of the semicircular, to 3 mm. at the turning point of the semicircular canal. As *Hinsberg* (5) remarks, luckily for the surgeons, the latter condition is the commoner of the two forms.

Furthermore, it should be borne in mind that the bulbus venæ jugularis occasionally interposes posteriorly and internally between the posterior semicircular canal, and the antrum. This

is presumed to be the case when the tympanic floor is found to be high and the bulb itself rises to some distance above the level of the floor of the external auditory meatus, and comes into view as the convexity of the external auditory canal is shaved down.

Regarding the surgical topography of the cochlea, it is to be remembered that the cochlea is bounded posteriorly by the fenestra ovalis, anteriorly by the carotid canal, inferiorly by the recessus hypotympanicus, and the jugular dome, while the geniculate ganglion and the facial nerve lie above it. Externally and below, the cochlea is represented by the outer wall of its first turn—the promontory.

From 25 specimens examined, *Bourguet* finds that the distance between the carotid canal and the oval window in 9 cases is 10 mm.; once he found it to be 10½ mm.; another specimen gave it as 12 and another as 13 mm. in distance.

The longitudinal axis of the cochlea is found to be constant, equaling about 9 mm., giving a distance of from 1 to 4 mm. between the cochlear tip and the carotid canal.

In 13 temporal bones, he either found the carotid canal in contact with the cochlea (4 times) or it was found to cover or overlie the cochlea on its external surface, to a varying degree (1 to 2 mm.). The latter observation is substantiated by the observations of *Körner* (6) and *Grüber* (7). In fact, it has been reported by *Hausen* (8) and *Rozier* (9) that the carotid canal may entirely overlie the cochlea.

Indications for the Surgical Opening of the Labyrinth : When a purulent process is present in the labyrinth, surgery offers the only rational treatment to combat its advance. Our aim is not simply to provide free drainage for the pathological accumulations in the labyrinth, and to prevent secondary infection from the middle ear, but to remove the extensive disease of the labyrinthine capsule and its connecting systems of canals.

A large number of competent observers, however hold it unnecessary to open the labyrinth, except in markedly severe cases; they content themselves with the performance of the radical mastoid operation and the free exposure of the middle ear spaces which results from this procedure. These surgeons

maintain that excellent and satisfactory results are thus obtained, and their claims seem to be substantiated by the published reports of many cases. Personally, we have observed cases where the symptoms of an involvement of the labyrinth completely disappeared after the performance of radical mastoidectomy. As *Hinsberg*, in his reports to the German Otological Society, in 1906, (10), pointed out, such testimony on closer examination is not the general experience where actual labyrinthine involvement exists. The published cases as a whole, on the contrary, tend to show, in the light of a better comprehension of these lesions, that our procedures, limited to the middle ear and halting at the outer wall of the internal ear, often directly arouse and call into activity a latent or quiescent process in the labyrinth, which often terminates in a fatal meningitis. Furthermore, the general sentiment now seems to be an endeavor to forestall the dangers resulting from labyrinthine involvement in every case where severe symptoms of purulent internal ear disease are present, by providing free drainage for the affected area through a wide opening of the labyrinth from the middle ear spaces, and by removing as much of the diseased bony labyrinth as possible.

Both these views have adherents. It is easily comprehended that the operative procedure in itself may break up the adhesions thrown out by an infective process, and thus break down the very barriers which nature interposes against the further advance of the inflammatory process toward the cranium; on the other hand, we have no means of estimating with any degree of exactness the dangers of labyrinthine infections which remain unoperated. (*Hinsberg.*)

The recent study of *Freytag* (11) of the literature of the operated cases which have been published, throws interesting light on this mooted question. Omitting all cases which presented sequestra formations involving the labyrinth, and 9 cases of healthy labyrinths reported to have been opened, *Freytag* has assembled 102 cases. Of 93 diseased labyrinths opened there were presented unmistakable symptoms of fatal complications 14 times before operation. These 14 cases should, therefore be deducted; 2 cases died of intercurrent disease. There

remain then 77 cases of uncomplicated labyrinthine involvement. Of these, 2 cases died in spite of operative measures, the operation, however, not contributing toward death; 1 case died because of the operation; in 6 cases the final result is reported as unknown. The remainder, 67 cases, were cured, giving a mortality of 4.2%. This exceedingly low mortality would seem to encourage further efforts toward anticipating the fatal outcome of a suppurating labyrinthitis.

During the last year, since *Hinsberg's* report was available, we have invariably operated upon the labyrinth when intracranial complications were threatened, or when the symptoms demonstrated purulent labyrinthitis; unfortunately, the mortality was higher than that given by *Freytag*. In three cases operated upon during this year, we had three deaths. It must be remembered that the statistics gathered by *Freytag* are the summarized results of a great number of observers, and cannot be cited as a standard for any one surgeon. Besides, the subject is still too recent to have given any one surgeon sufficient experience in a class of cases, which, according to *Friedrich's* estimates complicates only 1% of all chronic middle ear suppurations. Relying on the published cases of a number of surgeons, which *Freytag* carefully analyzed, I am of the opinion that the operation *per se* presents relatively small dangers to life. *Richards* recently reports on eleven cases, upon which he operated with three deaths, two of which he regards as due to imperfect technique; the third died of infective sinus thrombosis. It is to be regretted that the histories of his cases were not published in detail, so that an analysis of them would be possible.

It remains for future investigation to devise means whereby we can differentiate between labyrinthine cases which are curable without resort to labyrinthine surgery, and those for whose recovery operative interference is imperatively demanded.

Jansen bases his decision whether or not to resort to surgery, upon the severity of the symptoms and the extent of the diseased process. He includes such lesions as defects about the footplate of the stapes, and a general thinning of the walls of the semicirculars so that their interiors are observed through the almost transparent bone as indicating operation.

Heine (12) holds that the operation on the labyrinth is only justifiable when one is positive of the presence of pus in the labyrinth. This indication is quite sound so far as it goes, but cases often arise where the positive diagnosis of pus in the labyrinth is impossible before this structure is opened. Purulency in the labyrinth only gives evidence of its presence by disturbances of equilibrium or of acoustics, accompanied by deafness, dizziness and nystagmus. When fever, headache, vomiting and opisthotonos supervene, the pathological process has already invaded the cranium. It is in that class of cases, which often present no symptoms pointing to the labyrinth until meningeal irritations warn us of intracranial involvement, that the great difficulty in diagnosis is encountered. In some of my cases among infants, the only sign which marked the advance of the disease from the middle ear to the labyrinth, was the sudden appearance of facial paralysis, accompanied after some hours by vomiting. In two cases, the eroded semicircular was the point from which the invasion proceeded, and in a third, the infection entered the labyrinth through the ulcerated footplate of the stapes.

Heine does not believe in operative measures other than curettement of the defect in the semicirculars, and bases his conclusions on the fact that *Jansen* saw but one death in 121 such cases from 1889 to 1896. *Lucae* reports the same results with 2 deaths in 32 cases, and *Heine* adds 40 more cases from *Lucae's* clinic with no deaths (13). Summing up, therefore, we hold the operative opening of the labyrinth to be indicated:

1. When prior to the operation, total deafness is present in the affected ear, or when symptoms either of labyrinthine irritability or absence of labyrinthine reaction are present, or when fistulous tracts leading into the labyrinth are uncovered at the time of the radical operation.

2. When at the time of performing the radical mastoid operation, a fistulous opening into the labyrinth is not demonstrable, but where nevertheless, grave symptoms of labyrinthine irritation are present, which do not promptly subside after the performance of the radical mastoid operation. Furthermore, in those cases where labyrinthine symptoms appear *after* the radical operation, which do not subside upon loosening the wound

for a short time, and then suddenly present meningeal symptoms. In two cases seen during the last year this occurred. The radical operation evidenced a pathological dehiscence in the horizontal semicircular. In one, facial paralysis was present before the operation, and in the other, facial paralysis appeared at the end of the first week after the radical procedure. They showed a rise of temperature and finally symptoms of meningitis, from which they eventually died in spite of surgical procedures on the labyrinth and on the meninges.

These cases, in addition to those found in the literature, warn us that where pathological defects are observed at the time of the radical operation, the case should be kept under strict observation for a long time, and that although immediate surgical procedures are not indicated, the opening of the labyrinthine channels becomes imperative at the first sign of the development of a general purulent labyrinthitis from the circumscribed lesion, or upon the advent of meningeal invasion.

The Operation on the Labyrinth: The radical mastoid operation has either already been performed or must be undertaken before any surgery is attempted upon the labyrinth.

The final step before the surgery on the labyrinth proper begins is the entire removal of the remains of the posterior meatal wall, so as to expose the canal of the facial without, however, injuring the nerve. The anterior and the lower boundaries of the bony mastoid wound cavity are widened as much as possible—by thinning out the anterior wall and by lowering the elevated angle in the tympanic floor and the elevation of the meatal floor. As the cochlea is necessarily the seat of surgical procedures during the labyrinthine operation, we endeavor to exactly note the relationship of the cochlea to the carotid artery, by exposing that blood-vessel. To accomplish this, the anterior tympanic wall is shaved down considerably. The bone overhanging the mouth of the Eustachian tube is removed and the tensor tympani muscle eviscerated. The cavity is now cleansed and packed with gauze, soaked in adrenaline solution to give a bloodless field. It is easy to open the labyrinth when the disease has partly destroyed its external walls, and the necrotic defects point the way; it is a more difficult matter when the walls are not

tampons. (A tampon placed too tightly in the wound after the radical mastoid operation has been observed to give rise to symptoms of labyrinthine irritability and to cause partial facial paralysis; all these symptoms disappeared in a few hours after the tampons were loosened.)

3. When in addition to a purulent labyrinthitis, one or other of its intercranial sequelæ are present, or their advent is threatened. (Extra dural cerebellar abscess, cerebellar abscess, meningitis serosa, etc.)

4. When sequestra formations develop involving the labyrinth. Here the removal of the necrosed bone is indicated as soon as possible (*v. Stein*, 14).

5. Finally, when during the performance of the radical mastoid operation, the stapes is accidentally injured or dislocated, then it would seem wise in the interests of the patient—a view also held by *Hinsberg*—to open the labyrinth as soon as the disease has apparently spread from the middle ear to the labyrinth; in other words as soon as symptoms from the labyrinth are observed.

Contraindications: Operative interference on the labyrinth is contraindicated, when only a partial involvement of this structure is present—in a circumscribed involvement of one or other of the semicirculars. Here it is better to wait until more definite symptoms develop. *Hinsberg* and *Heine* hold that, as soon as the primary foci of the purulent process is eradicated in these cases, the circumscribed disease in the semicirculars will usually heal.

We have repeatedly noted this to occur in cases where the horizontal semicircular canal showed a defect in its contour at the time of the radical operation; this, however gave no subsequent unpleasant sequelæ and apparently healed entirely. In two of these cases, symptoms referable to the labyrinth existed before the radical operation, viz., dizziness and some nystagmus, which, however disappeared afterward, and the patients made a full recovery.

This class of cases demands the strictest observation, as frequently in cases where at the time of the radical mastoidectomy, an opening into the semicircular is noted, the patients do well

for a short time, and then suddenly present meningeal symptoms. In two cases seen during the last year this occurred. The radical operation evidenced a pathological dehiscence in the horizontal semicircular. In one, facial paralysis was present before the operation, and in the other, facial paralysis appeared at the end of the first week after the radical procedure. They showed a rise of temperature and finally symptoms of meningitis, from which they eventually died in spite of surgical procedures on the labyrinth and on the meninges.

These cases, in addition to those found in the literature, warn us that where pathological defects are observed at the time of the radical operation, the case should be kept under strict observation for a long time, and that although immediate surgical procedures are not indicated, the opening of the labyrinthine channels becomes imperative at the first sign of the development of a general purulent labyrinthitis from the circumscribed lesion, or upon the advent of meningeal invasion.

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destroyed; or, when the labyrinthine infections have resulted from an invasion through the fenestra ovalis.

Exact anatomical knowledge of the parts, combined with technical skill in carrying out the details of the procedures, is an absolute necessity to successful surgery. The preliminary surgical procedures must be done as rapidly as possible, so as to save time for the more delicate work on the labyrinth.

Jansen, to whom we owe the first systematic plan for operating on the labyrinth, advocates entering the internal ear from the vestibulum. He follows the rear branch of the horizontal semicircular canal; after opening its lumen with a small chisel, he follows the canal upward and around toward the rear, using a small drill for this purpose; he employs this procedure especially in cases where he suspects deep-lying extradural abscesses, cerebellar abscess, etc. In these cases he removes the rear side of the temporal pyramid, at the same time exposing the dura as he advances. *Neuman* (15) also advocates this plan in similar cases, following up the channels of the labyrinth to the internal auditory meatus. By this maneuver, he not only opens the diseased semicircular and the vestibulum, but also exposes, and in certain cases, opens into the posterior cranial fossa. The operation is completed by opening the cochlea at the promontory.

Hinsberg, who was annoyed while performing this procedure on the semicircular, by losing his guiding landmarks because the bone fragments filled the semicircular canal lumen, advocates the entrance to the vestibulum through the fenestra ovalis. He opens at this structure with a rotary drill, and traces the canals from the entrance thus obtained by means of a probe which he introduces into the canal (16). The cochlea is opened from the fenestra ovalis, by removing the promontory, working downward.

Botey (17) published a method somewhat similar; it differs from the above in that he proceeded from the posterior branch of the horizontal semicircular and thus enters the labyrinth.

Richards (3) has recently devised a procedure which is very ingenious and fully opens the entire labyrinth. The steps of the operation as advocated by *Richards* are as follows:

1. The *Schwartze-Stacke* operation is first completed by exen-

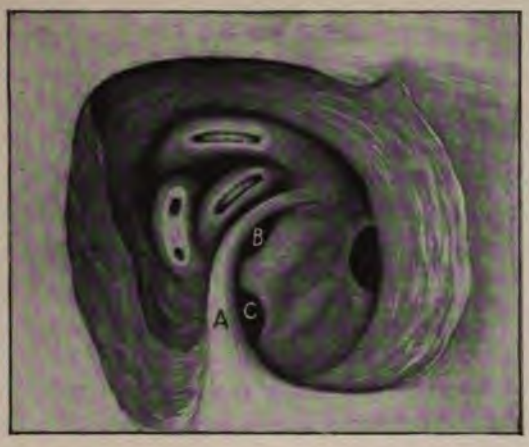

FIG. 51.—ILLUSTRATING STEP IN THE RICHARDS OPERATION ON THE LABYRINTH.

A, Bony Canal of the Facial. B, Oval Window. C, Round Window. The Semicircular Canals are Open. (After Richards, with Permission.)

FIG. 52.—Steps in the Richards Operation on the Labyrinth. The Partial Eradication of the Horizontal Semicircular Canal (C) Has Lowered the Plane of the Bone at this Point so as to Partially Expose the Facial Nerves for a Small Area. At B, the Cochlea is Open. The Opening Seen Anteriorly and Above Exposes the Cochlear Apex. (After Richards, with Permission.)

PLATE XVIII

terating the mastoid cells as extensively as possible to secure the greatest possible amount of working room. The facial ridge is lowered to its absolute limits. The hypotympanicum and lower level of the auditory canal floor are planed off so as to expose to its utmost the lateral (outer) wall of the vestibule, and the dome of the jugular bulb, should the latter rise high. The convexity of the external auditory canal floor is lessened; the Eustachian tube orifice fully exposed, and the tensor tympani evulsed. Finally, if possible, the arches of the semicircular canals are delineated by removing the osseous tissues surrounding them.

2. The prominence of the horizontal semicircular canal is then removed. This is done by placing a chisel at a point somewhat below its summit, but well above the level of the Fallopian canal. The stroke of the chisel should correspond to the direction of the plane of the canal. This uncaps the horizontal semicircular canal.

3. The remaining canals are next uncapped. A curved gouge is used to open the superior semicircular canal. (Fig. 51.)

4. The vestibule is now entered through the solid angle creating a pit at the juncture of the semicirculars: the point of this is directed inward. This depression is gradually lowered, until the vestibule is opened. The inner lip of the horizontal semicircular canal must be removed. *Richards* advocates that the chisel be held perpendicular to the plane of cleavage during this maneuver. The instrument must not impinge upon the outer lip, as this is in intimate relationship with the facial canal. This lip *Richards* leaves *in situ* as a bridge carrying the nerve. (Figs. 52 and 53.)

5. The vestibular opening is now enlarged until full exposure of its cavity is obtained. A search of its inner wall for fistulæ is made. Care must be exercised not to injure the bridge of bone supporting the facial when enlarging the vestibular opening for this purpose. A small, sharp gouge is the safest instrument to use. Occasionally extensive necrosis necessitates sacrificing the bony ridge which supports the facial. To avoid injuring the nerve, the bone is shaved off from above downward, in a direction parallel to the nerve. This leaves the nerve in a gutter of bone from which it may be carefully lifted. (Fig. 53.) At this portion of its course the nerve occasionally gives off filaments.

These should not be torn, but should be cut. As much of the supporting bridge is then removed as is found to be necrotic. In knocking away the bony portion which represents the upper and the inner wall of the tympanic cavity, the chisel should never be used in a direction from behind forward, paralleling the nerve's course, but from above downward, or from before backward, in a direction perpendicular to the course of the nerve and the Fallopian canal.

A complication to this maneuver is found when the Fallopian canal splits off in a cylindrical section, usually because of lack of attention to the directions for the use of the chisel given above. The removal of the little cylinder is the next objective—if this accident has happened. The little cylinder is grasped in the jaws of a mouse-toothed forceps and a pair of rongeurs, and the little cylinder is crushed in a direction parallel to the course of the nerve. Where care has been exercised to convert the Fallopian canal into a gutter, this complication will not occur.

6. The anterior-inferior cavity of the vestibule is now exposed. A gouge, whose width equals that of the distance between the round and the oval windows, is placed on the bone separating these structures, and with a stroke delivered from above, downward, and forward, the posterior part of the promontory is fractured. The opening thus made is enlarged until the vestibular cavity, together with the beginning of the first cochlear turn is fully exposed. When it is found that the disease has invaded the cochlea, this structure must be explored.

7. Working from behind forward, exposing its interior to a point just short of the carotid eminence, the roof of the first cochlear whorl is removed. For this purpose a thin, sharp gouge, having no shoulder, and having a width equal to that of the cochleal whorl is used.

8. The further exploration of the cochlea follows. A point is selected on the cochlear shell, corresponding to its apex. This is shaved down until the dark interior shows through the thin lamella of bone. The opening is made by means of a chisel stroke delivered from above downward and forward in a direction corresponding to that held by the cochlear whorl. Thus a window

FIG. 53.—A Step in the Richards Operation. The Facial Nerve, A, is Shown Lifted Out of a Gutter of Bone. B, left in Situ as a Support for the Nerve. (After Richards, with Permission.)

PLATE XIX

is created in the cochlear shell which is gradually enlarged until the upper cochlear cavity is exposed.

9. The second half of the cochlear whorl is exposed, by removing the shell from the apex of the pyramid downward to a point corresponding to the termination of the first turn. With a small gouge, the roof is carefully broken away from above, and the entire interior of the cavity of the cochlea is now exposed. The operation is thus completed. Occasionally exenteration of extensive portions of the petrosal pyramid is necessary. If necrosis is present it indicates this additional step.

Points of Technique in the Richards Operation : When opening the horizontal semicircular canal, the cutting edge of the chisel should be placed at a point below its summit, but above the level of the Fallopian canal, to avoid a plane of cleavage which may involve the facial nerve.

The semicirculars are uncapped by making the strokes in a plane taken in their direction.

The labyrinthine fluid is apt to be mistaken for blood or disintegrated granulations in the lumen of the semicirculars, because of the contrast presented by the dark interior of the canals against the brilliantly white bone which surrounds their lumen.

In opening the vestibule, the chisel or gouge must not be held perpendicularly to the line of cleavage, and must not be permitted to impinge against the bridge of bone intimately connected with the Fallopian canal. Attention to this same structure becomes imperative when enlarging the vestibular opening and searching its interior for fistulæ.

After the removal of necrotic areas of the bridge carrying the facial, an attempt is made to preserve some part of the support for the nerve. Efforts are advocated to prevent elongation or sagging of the nerve. Furthermore, when exposure of the nerve becomes necessary, no attempt should be made to retract it or to draw it to one side. The facial nerve is liable to injury against the serrated margins of the Fallopian canal. Efforts to draw the nerve aside may injure it. They usually stretch it and subsequently cause it to become imbedded in granulations. The nerve should be carefully lifted without pulling.

Richards recommends that the greatest care should be taken

that the cutting chisel does not cross the vestibular cavity and impinge upon its inner wall. The inner wall bulges outward and is separated from the internal auditory meatus only by a brittle bone partition, not more than $\frac{1}{32}$ of an inch in thickness. Where the inner vestibular wall is fractured, cerebrospinal fluid is lost, and the cranial cavity opened. Intracranial infection is then to be feared.

In removing the roof of the first cochlear whorl, four structures are to be avoided. These are the dome of the jugular bulb below, the eminence of the carotid in front, the base of the modiolus and the internal auditory meatus medially. The danger to the latter two structures is a potential one, and must be kept in mind. Injury to these also opens the way to intracranial invasion.

The injury of the modiolus is avoided by confining the removal of bony shell entirely to the roof of the first turn and not permitting the instrument to impinge upon its inner wall. Furthermore, if the chisel stroke is applied to the cochlear pyramid, the fracture will usually take place at the base, according to *Richards*. The internal auditory meatus is consequently opened. *Richards* reports that the death of one of his cases was due to this technical error.

In enlarging the opening made at the apex of the cochlear pyramid, care should be exercised that the back of the instrument does not impinge upon the modiolus, lest its fracture result.

In a great number of cases, the simple curettement of the diseased area, the fistulous tracts, as recommended by *Heine*, suffices. In others, an extensive radical procedure, such as described above, affords the only chances of ultimate recovery. Which of these measures is to be employed must necessarily depend upon the extent of the lesion present, whether or not intracranial complications are already in existence, or whether the disease is localized to the labyrinth.

Hinsberg, *Heine*, and others recommend as circumscribed an operation as possible for the uncomplicated cases.

Discussing the various procedures advocated, *Bourguet* points out that at the beginning of the operation, the posterior branch

of the horizontal semicircular possesses the advantage of making the site of election for entering the labyrinth as remote as possible from the facial nerve. The disadvantages of this procedure, however, are apparent, if the jugular bulb lies high, as then injury to this structure may occur. The sinus petrosa superior is likewise liable to injury, when the posterior branch of the semicircular is the primary seat of surgical intervention. Furthermore, a slip of the chisel, while working in the region

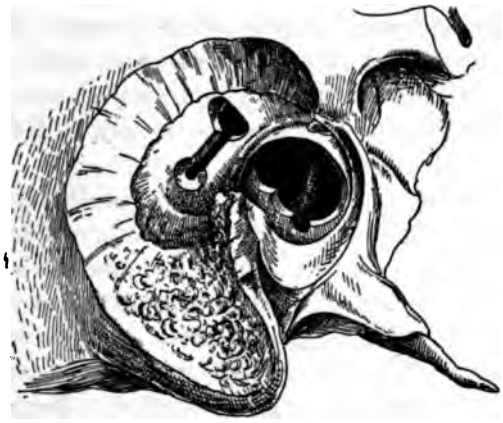

FIG. 54.—The Bourguet-Hinsberg Method, Showing the co-relation of the Labyrinthine Surgery to the Mastoid Wound Cavity. The Internal Ear Channels are Open.

near the internal auditory meatus, will undoubtedly injure the facial.

Hinsberg's method also endangers the nerve, but if the use of the probe is carried out simultaneously with the removal of bone, this danger is reduced to a minimum.

Bourguet devised a protector to lessen the danger to the facial. This instrument, whose top is a flattened plate of metal, S-shaped, is placed over the facial. The concave cup marks the spot where the drill enters the semicircular. These instruments are made in pairs, one for the right and one for the left side.

The operation, according to *Hinsberg*, proceeds as follows: (Fig. 54):

1. The radical mastoid operation is performed with special care to remove as much of the posterior meatal wall as possible.

The parts should be freed of blood by soaking them in adrenaline, and the operative technique is carried out under bright illumination.

2. Introduction of a drill at the fenestra ovalis, and from this point of entrance carefully removing the lateral (outer) labyrinthine wall down to the fenestra rotunda. This opens the cochlea and the vestibulum.

For further evisceration of the cochlea, he employs the sharp curette or the chisel, instead of the drill.

During the maneuver, care should be exercised that the drill does not slide off from the oval window upward, as then the facial nerve is liable to injury; and furthermore, in opening the cochlea, as we near its deeper extremity, collision with the carotid is possible.

As the deeper parts of the cochlea are curetted, care must be exercised not to slip into the internal auditory meatus.

3. The *Bourguet* protector is now introduced, or, a probe is introduced into the fenestra ovalis and pushed upward, underneath the facial. The tip of this probe is introduced into the anterior branch of the horizontal semicircular canal, and an accurate idea is obtained of its orientation. The drill is then applied over the semicircular and its outer wall removed, care being taken not to let it slip downward and injure the facial nerve.

Hinsberg advocates the drill for these procedures and recommends keeping the instrument cool by dipping it occasionally in a solution of boracic acid. He warns us that if this detail is neglected, bone necrosis may later occur resulting from the heat of the drill. He deprecates the use of the chisel, as the bridge of bone supporting the facial might possibly be broken down by the strokes of the hammer, to the injury of the facial nerve.

Finally, I desire to call attention to what *Hinsberg*, *Cheatle* (18) and *Richards* have already remarked, that the operation is so drawn out in length of time that the patient suffers from its effects. *Cheatle* recommending that when the radical has not already been performed, that it be done first and the labyrinth operation undertaken a day later.

Personally, we have followed the *Hinsberg* procedure in our cases, except that we have exclusively used the chisel and curette. In those cases in which we operated, the nerve was destroyed and its ends found imbedded in granulations. The problem of saving it was not, therefore, before us. In the event of an uninjured nerve, we hold the *Richards'* procedure to be the best, as it keeps the nerve in full view and the underlying bone is easily removable.

Regarding injury to the nerve, if we revert to *Freytag's* statistics already referred to, we note that of the cases reported, there were 19 cases with facial paralysis present before operation; 17 times the nerve was injured during the surgical procedures, and in 39 cases there are no notes on the condition of the facial. This gives 27 cases wherein the nerve was uninjured. Of those injured during the operation, a majority of the patients recovered from their facial paralysis after a lapse of time.

Operative Findings: Generally in the operative findings we demonstrate whether or not a general labyrinthine involvement is present or absent. Occasionally, however, even at the operation, this question remains unanswered.

In opening a labyrinth, the seat of a diffuse purulent process, the absence of a flow of cerebrospinal fluid from the labyrinth is a significant factor, which we have observed in all our cases—a finding to which *Hinsberg* also calls attention. Furthermore, *Hinsberg* has always noted the escape of cerebrospinal fluid when a healthy labyrinth has inadvertently been opened. In encapsulated or circumscribed labyrinthitis, a flow of cerebrospinal fluid is often noted.

Friedrich (19) and *Hinsberg* differ as to the diagnostic value presented by the presence of a flow of labyrinthine fluid when an accidental opening has been made into a semicircular canal. The former attaches no importance to this sign, while *Hinsberg* places a diagnostic value on the absence of the flow, taking it to mean an encapsulation against further invasion, the flow reappearing after the curette had destroyed such adhesions. We give both views, as personal observations on this point are lacking. In all the cases upon which we operated, the labyrinthitis was general, and a flow of cerebrospinal fluid was not noticed.

Value of the Operation: In discussing the indications for this surgical measure, we quoted *Freytag's* conclusions, arrived at from an analysis of the published cases. The mortality from the operation was found to be about 4.2%.

Once the unchecked infection reaches the cerebellum, the mortality is high. When therefore, the difficult technique of this operation is better understood and more fully worked out, it will often be employed to anticipate the almost certain fatal sequelæ of a purulent labyrinthitis. At present, the cases when first seen by us are too often so far advanced that surgical intervention is unavailing.

After-treatment: Immediately after operation, when the patient emerges from the anæsthetic, there are often seen post-operative evidences of labyrinthine irritation—dizziness—nystagmus, etc. This is especially the case where there has been an escape of cerebrospinal fluids during the operation. In other cases such symptoms are often entirely lacking.

Upon the completion of the surgical procedures, the entire cavity is washed and cleansed with normal salt and weak bichloride of mercury solutions. The post-auricular incision is kept open, pending the outcome of the surgical measures.

The tampons placed in the wound should be very loosely packed and not pressed tightly into the labyrinth. If the case progresses favorably, the first change of dressing is made after five or six days; whenever the outside dressings are soiled they may be changed, without however disturbing the dressings in the deeper portions of the wound.

If fever or other alarming signs develop the dressing is immediately changed. In cleansing the wound cavity care should be taken not to rub the facial nerve with the gauze, as the nerve is quite as easily damaged in this way as at the time of operation. A vaseline covering for the nerve, as recommended by *Richards*, is advocated.

If there is a strong outflow of cerebrospinal fluid, the dressings soon become saturated; in such cases outer dressings are more often changed. After five days such outflow is rare (*Hinsberg*).

v. Stein drains the internal ear by means of silk threads. He uses hydrogen peroxide as his cleansing agent. The principal

thing to guard against is the obstruction of drainage from the internal ear through the growth of granulations in the outer wound cavity. Such must be carefully removed with curette or chromic acid pearls.

Persistent, exuberant granulations suggest the formation of sequestra, and necrotic areas are then to be sought for. Often a rapid recovery follows the removal of small pieces of necrotic bone.

Healing in the opened labyrinth usually takes place through the formation of healthy, firm granulations in the wound depths, which gradually grow toward the surface. Later when the plastic flaps have been cut, the epidermatization of the external wound cavity takes place similarly to that seen after the radical operation.

Results of the Operation: The operation on the labyrinth usually results in total deafness, with symptoms of absence of functional activity from the affected semicirculars.

Richards (3) reports that following the exenteration of the labyrinth, the patient may be exceedingly sensitive to noise and to loud musical sounds. He reports that where patients had been subjected shortly after operation to loud musical sounds as the playing of the piano, they exhibited dizziness and vertigo.

Where the facial nerve has been exposed throughout its entire extent, paralysis supervenes, even when the nerve is uninjured. When the nerve is uninjured, partial improvement may be expected after five or six months, under facial massage and appropriate electrical stimulation. If the nerve is severed, the recovery from the paralysis is doubtful.

Subsequent to operation, meningitis may result. Its onset is usually prompt—in from one to three days—and its termination rapid.

Richards reports the advent of large quantities of sugar and acetone in the urine, with the clinical picture of diabetes, as noted occasionally after the operation. He holds this as suggesting the profound systematic shock to which the operation subjects the patient.

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CHAPTER IX

OPERATIONS ON THE BLOOD-VESSELS

Historical—Anatomical—Anatomy of the Internal Jugular Vein—Topography of the Internal Jugular Vein—Surgery of the Accidentally Exposed but Uninjured Lateral Sinus—Surgery of the Accidentally Injured Sinus (Dangers)—Varieties of Thrombosis—Surgical Signs Pointing to Thrombosis—Indications for Employing Test-puncture of the Lateral Sinus—Dangers of Test-puncture—Indications for Opening the Sinus—Contraindications for Opening the Sinus—Indications for Ligature or Resection of the Internal Jugular—Indications for Jugular Ligature (Resection) Before, At and After the Sinus Operation—Operation of Exposure of the Sinus—Opening of the Sinus—Resection of the Jugular—Dangers Presented—After Effects—Hindrances to the Operation on the Jugular—Results of Various Procedures—Untoward Sequelæ—After-treatment.

Historical: *Hooper* as early as 1826 correctly recognized both sinus phlebitis and sinus thrombosis.

Other early observations recorded are those of *Abercrombie*, 1835, *Bruce*, 1840, *Virchow*, 1845, and *Sedillot*, 1849.

In 1856, an accurate description, based on personal observations and accompanied by a citation of cases, was published by *Lebert* (1). The reports of *Dusch*, *Gerhardt*, *Griesinger* and *Heubner* (2) followed.

Ligature of the internal jugular vein was first advocated by *Zaufal* (3), in 1880. Because expectant treatment almost invariably meant a hopeless prognosis, *Zaufal* ligated the internal jugular and incised the affected sinus, at the time of mastoid exenteration in an effort to prevent dislodged pieces of a thrombus from entering the general circulation. In 1884, he reported on a case wherein, after performing his mastoid evisceration, he opened, washed and drained the diseased sigmoid sinus. Death resulted, however, from metastatic lesions in the lungs (4).

In 1886, *Horsley* (5), recommended a mode of treatment similar to that advocated by *Zaufal*, at the same time reporting a case in which the sinuses of both sides were opened and both jugulars tied. The case is reported to have died from the effects of shock.

General interest in the subject of sinus thrombosis was aroused by the reports published by *Lane* (6), 1899, and *Ballance* (7), 1890, and from that time on many valuable contributions have been added to our knowledge of this complication of middle ear disease.

Anatomy: The lateral sinuses are the largest of the cranial blood-vessels. They extend from the internal occipital protuberance to the jugular foramina, terminating at the beginning of the internal jugulars at the jugular bulb. They pass downward, outward and forward, on both sides of the head, and in their course groove the squamous portion of the occipital, the posterior inferior angle of the parietal, and the mastoid portion of the temporal bones. (See Fig. 55.)

The lateral sinus is divided anatomically into the horizontal or lateral portion, and the sigmoid portion. The point where these anatomical sections meet and where the lateral portion takes a sharp turn downward and forward, is designated the "knee" of the sinus.

The horizontal portion of the sinus (often designated the lateral sinus) is situated at the base of the tentorium cerebelli. This portion of the vein is triangular on section, with its base directed toward the occipital bone. The sigmoid portion of the sinus is semi-cylindrical on section, especially that portion of it which lies below the tentorium cerebelli.

The superior petrosal sinus empties into the sigmoid sinus near its posterior end; the mastoid emissary vein empties into it, somewhat below and behind the posterior end of the sigmoid section of the lateral sinus; and the inferior petrosals empty into the jugular bulb. (See Figs. 55 and 61.)

There is considerable difference in the position of the sinus on the two sides of the skull, which must be taken into account when operating on this section of the head. The sigmoid sinus is usually further forward; that is, it is nearer the external auditory meatus, the tympanic cavity and the mastoid antrum

on the right side than it is the case on the left side. According to *Körner* (8) this difference between the two sides averages about 2.55 mm. This observer drew attention to the fact that skulls of brachycephalic type usually present the middle cranial

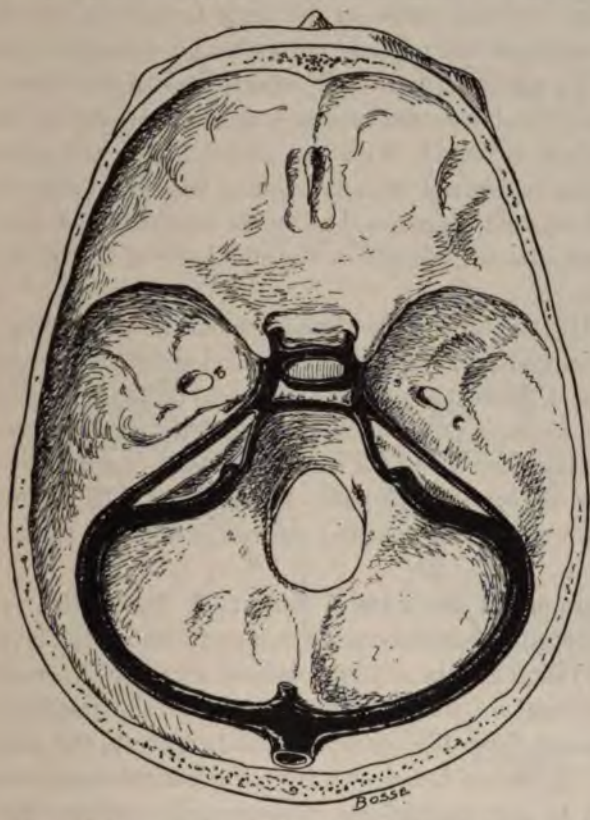

FIG. 55.—General Topography of the Cranial Blood Sinuses, Seen from Above, Showing the Torcular Herophili, the Stump of the Straight Sinus, the Lateral Sinus, the Sigmoid Sinus, Superior Petrosal Sinus, the Inferior Petrosal Sinus, the Transverse Sinus, the Cavernous Sinus, the Circular Sinus.

fossa and the fossa signoidea nearer to the external auditory canal, the tympanic cavity and the mastoid antrum than is found to be the case in skulls of the dolichocephalic type of contour.

Trautmann (9) found the sinus further forward in skulls which present an angle greater than a right angle, at the junction

of the posterior osseous meatal wall and the skull cortex; that is, in skulls where the posterior meatal wall markedly slants toward the interior, and with the suprameatal spine of *Henle* situated somewhat medianly.

Whiting (10) also relies on the angle formed by the posterior meatal wall and the mastoid cortex for an estimate of the position of the sinus. *Okada* (11) reports finding the sinus further forward in small mastoid processes than in cases where the mastoid process is large. With this latter finding the writer disagrees, since he has not been able to find the sinus further forward in small mastoid processes, but on the contrary has often found the vessel situated relative to the small size of the process quite far back.

Held (12), measuring the distance from the protruding portion of the sigmoid sinus to the suprameatal spine in 463 adult temporal bones, finds the average distance to be 12 mm. The greatest distance he reports at 23 mm., and the other extreme was found in one case where the sinus was in direct apposition to the posterior osseous meatal wall. He reports the sinus interposed between cortex and mastoid antrum twice in the series he examined.

Topography of the Lateral Sinus: A line drawn from the external occipital protuberance to a point about the level of the superior margin of the external osseous meatus, (*Macewen* (13)), will represent in its posterior two-thirds the position of the lateral sinus, from the occipital protuberance to the knee. See Fig. 56. A second line drawn from the parieto-squamo-mastoid junction to the mastoid tip, following, if possible, the line of the obliterated but often discernible squamo-mastoid suture, will, in a general way, outline the position of the sigmoid sinus. (See line E,B, Fig. 56.)

Anatomy of the Internal Jugular Vein: Commencing at the jugular bulb, the internal jugulars run in a diagonal course down the side of the neck, at whose root they unite with the subclavian veins to form the innominates.

At its commencement, the internal jugular lies upon the rectus capitus lateralis, and behind the internal carotid artery and the nerves which pass with it through the jugular foramen. At a

somewhat lower plane, the internal jugular and the carotid lie upon the same level, with the glossopharyngeal and hypoglossal nerves passing between them. The pneumogastric descends between vein and artery in a position somewhat behind them, but

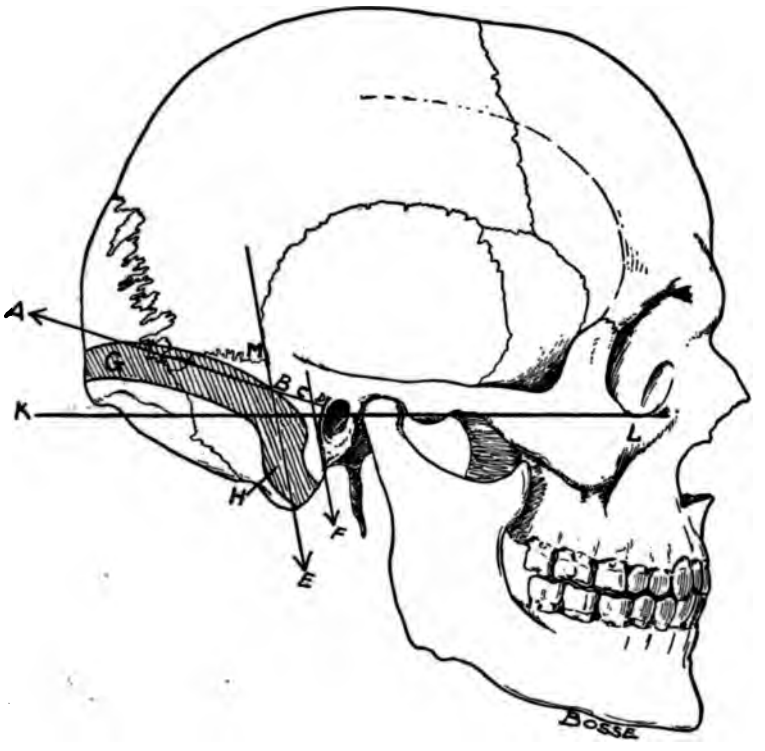

FIG. 56.—TOPOGRAPHY OF THE LATERAL AND SIGMOID SINUSES, ON THE SIDE OF THE SKULL.

K-L, Reid's Base Line. G, Lateral and Sigmoid Sinuses (H) the Posterior Two-thirds of the Line A-B Gives the Lateral Sinus. The Line B-E Indicates the Position of the Sigmoid Sinus. Line C-F Skirts the Post Meatal Wall. D, Henle's Spine.

nevertheless in the same sheath as the vessels. The spinal accessory nerve crosses obliquely outward behind the vein.

At the root of the neck, the vein of the right side is placed at a little distance from the artery; on the left side, it usually lies over the artery at its lowest part. The right internal jugular crosses the first part of the subclavian artery.

The internal jugular vein is of considerable size, but varies in individuals; the left is usually the smaller. In its course, the internal jugular receives the facial, the lingual, the pharyngeal, the superior and the inferior thyroids, and, occasionally, the occipital vein.

Topography of the Internal Jugular Vein: The side of the neck can be outlined as a somewhat irregular quadrilateral space.

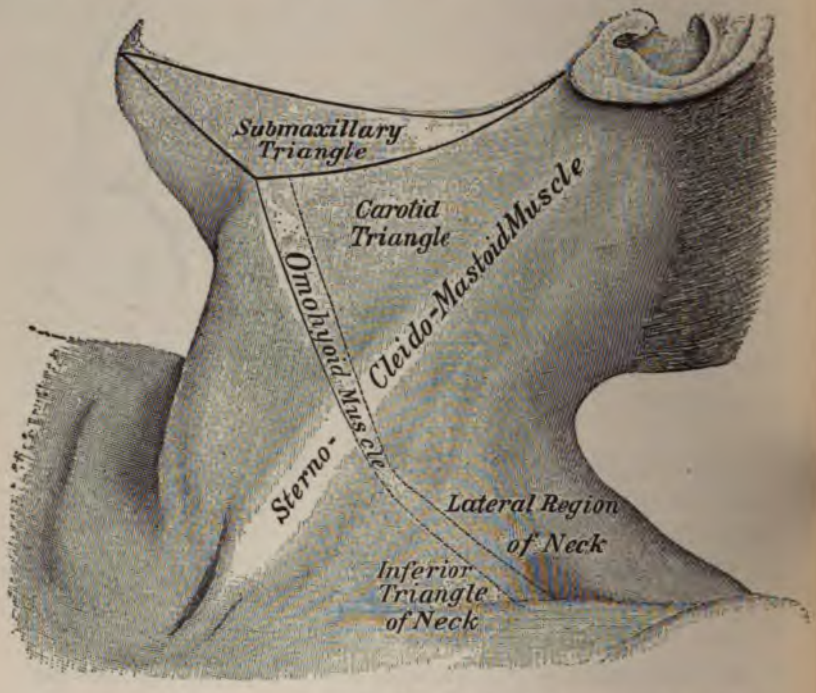

FIG. 57.—The Triangles of the Neck, from the Side. (After Bardeleben).

The upper boundary of this space is the lower border of the body of the jaw and a line from the angle of the jaw to the mastoid process. Below, the space is limited by the prominent upper outline of the clavicle. In front, the median line of the neck limits the area, and behind, its outline is bounded by the anterior border of the trapezius. (See Fig. 57.)

This quadrille space is divided into two triangles by the sterno-mastoid muscle, extending obliquely from the mastoid process

above, to the clavicular end of the sternum below. (See Figs. 57 and 58.)

The jugular vein takes its course along the anterior border of the sterno-mastoid muscle, lying somewhat underneath and occasionally a little behind the anterior border of the muscle.

The anterior border of the sterno-mastoid muscle, whose posi-

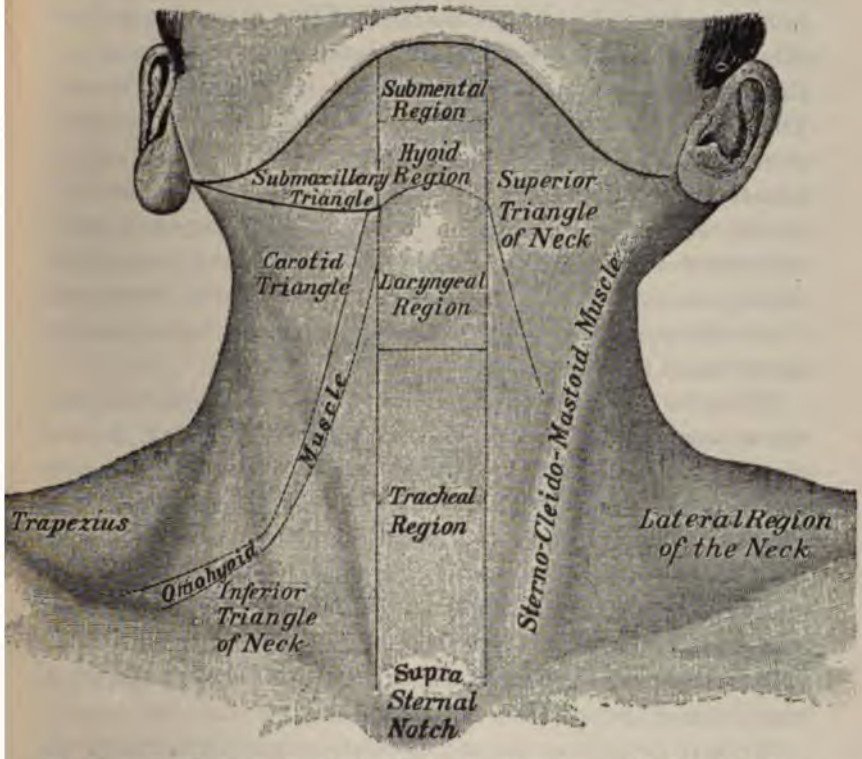

FIG. 58.—The Topography of the Neck, from in Front, Outlining Guiding Landmarks.

tion is generally easily felt through the overlying skin and fascia, is the surgical guide to the incision which exposes the vein either for ligature or for resection. (Fig. 58.)

The Surgery of the Accidentally Exposed but Uninjured Lateral Sinus: When curetting the mastoid cells in the region of the sigmoid sinus, whether in acute or chronic cases, the thin tablet of bone overlying the sinus is sometimes removed, exposing the

sinus wall to view. If the vessel wall itself is uninjured by the procedure, very little danger need be apprehended from the accident.

Such unintentional exposure of the sinus usually happens in cases where the disease has so softened the bone, that it easily breaks down under our attack. Reasonable care in handling the curette when operating in this region, will often save the sinus from exposure. The danger lies in the failure to remove splinters of bone which may become impacted between the vessel's coat and the surrounding bone after its bony casement has been opened. These splinters should be carefully removed by means of a small blunt hook or forceps. Splinters are often overlooked, and are sometimes only noticeable when it is observed that the vessel wall stands off from its bony canal. If permitted to remain in place, they act as irritant foreign bodies, and may set up local inflammatory reactions which eventually may involve the vessel walls if they do not lead to the more serious complication, namely, compression thrombosis.

When the sinus is accidentally uncovered, it is well to enlarge the exposed area and cover the sinus wall with a light tampon of iodoform gauze. This should not be pressed into the bone opening, but lightly laid over it. The tampon, moistened with absolute alcohol, is kept in place during the exenteration of the mastoid cells, which proceeds as if no accidental exposure of the sinus had taken place. At the termination of the operation, a separate piece of gauze is placed over the exposed sinus, and the rest of the dressing applied as already described in the after-treatment of the mastoid.

We have never observed any ill effects to result from the simple exposure of the sinus, when the accident was handled as just described.

The Surgery of the Accidentally Injured Sinus: When the coat of the sinus is ruptured or lacerated by instrumentation during the evisceration of the overlying mastoid cells, then the dangers of sequelæ are increased.

Dependent to a great extent upon the stage of the mastoid operation in which the accident occurs, injury to the sinus not only presents dangers inherent to the lesion, but it also handi-

caps the surgeon in the satisfactory completion of the operation on the mastoid.

If the sinus is found far forward, the accidental rupture of the walls of this blood-vessel may occur very early in the operative procedure. The ensuing hemorrhage through the small opening is not only difficult to control, but it obscures the operative field. Added to this are the risks which follow laying open a large blood-vessel to infection from a suppurating mastoid.

The treatment of the accident consists in deftly introducing a plug of iodoform gauze moistened with absolute alcohol into the bone opening, and pressing it against the tear in the sinus wall.

The hemorrhage thus controlled, the plug is held in place by an assistant, and the enlargement of the mastoid excavation is continued rapidly until the bony tablet covering the sinus is outlined on both sides of the injury. Plugs of iodoform gauze to control the hemorrhage are then insinuated between the bony casement and the sinus wall, both above and below the site of the injury. The plug held by the assistant is now removed and the wound in the vessel wall carefully examined.

If the wound is found to be small and its edges can be brought together, then a suture of the tear may be tried. In placing such a suture, the thread should penetrate only the outer coats of the blood-vessel, the serous lining being spared when passing the suture. A plug of iodoform gauze is placed over the sutured wound, and the plugs shutting off the blood circulation are removed. This method is not often applicable because the laceration of the vessel wall is usually not a smooth, incised wound, but rather an irregular tear whose jagged edges cannot be brought to proper coaptation.

Very small lacerations, and puncture wounds, are treated by placing a plug of iodoform gauze moistened with absolute alcohol over them. The amount of pressure exerted when the plug is first placed in position at the time of the accidental injury, can usually be lightened before the final dressing is placed in the mastoid, thus preventing an obliteration of the lumen of the blood-vessel. We have observed cases where the patency of the blood-vessel was thus re-established, and no untoward sequelæ followed the accident.

When the laceration of the sinus wall is of such a nature that its suture is impossible, or the wound in the vessel's wall too large to be checked safely by a tampon placed over it, a temporary gauze pad held by an assistant controls the hemorrhage until the proximal and distal ends of the sinus are closed by small gauze plugs. These are insinuated between the bone and the vessel walls, compressing the walls so as to occlude the lumen. Where the accident happened before the operation is completed, the mastoidectomy continues after the hemorrhage is under control.

The gauze plugs placed upon the vessel to control the hemorrhage are generally left *in situ* for at least seven days. They are not disturbed at the first change of dressings.

When the jugular bulb is accidentally opened while curetting the tympanic floor, an attempt may be made to control the hemorrhage by placing a plug in position at the point of injury. Usually it will be necessary to ligate the internal jugular, and occlude the sinus by a compression plug placed on the sigmoid side of the bulb. This accident is the most serious of the series.

Dangers: The simple uncovering of the sinus presents little, if any, danger; extensive exposure and even opening of the blood-vessel is almost without danger if properly executed. That this accident must not be lightly considered, however, is shown by grave sequelæ reported by *Grünert* and *Zeroni* (14), by *Panse* (15), and *Körner* (16).

The greatest source of danger lies in the instrument employed; the chisel, the gouge, or the curette, may be the possible carrier of infection to the blood-vessel, and thus directly invade the blood-stream.

In all cases where such accidents occur, it is well to look for symptoms referable to sinus complications. When such symptoms develop they should be treated in accordance with their gravity.

Varieties of Thrombosis: Irrespective of the sinus involved, thromboses are divided upon clinical characteristics into two general types: the non-septic and the septic thrombus.

Pathologically, they are divisible into two general classes, the

wall thrombus and the obstructing thrombus. The latter is usually of the septic type; the former may be either septic or non-septic in character.

Leutert (17) believes all thrombi are septic, and advocates their removal; we agree with *Jansen* and *Heine* that non-septic sinus thrombi may occur as the result of a mechanical compression of the sinus wall. Such pressure may be made by pus and detritus in a purulent mastoid cavity. In such cases it often happens that no symptoms referable to the sinus are present at any time during the disease of the ear. We have seen cases of this class recover completely after evisceration of the purulent contents of the diseased mastoid.

The sinus wall is exposed to the purulent contents of the mastoid cavity; occasionally it is bathed in actual pus, forming a condition which we designate "perisinus abscess." Upon cleansing away the detritus, the sinus wall is found covered with granulations; these are easily wiped off. The sinus wall itself is discolored, often thickened, and if exposed for any extent, the demarcation of the diseased from the healthy portion of the sinus becomes evident.

At times, portions of the discolored part show indentations, or present a rather sunken-in appearance. Usually pulsations are present; the absence of these does not necessarily mean an obstructing thrombosis. Whether the vessel contains blood or not can be demonstrated by making a test puncture through its thickened wall.

In the majority of cases, the thrombosis is found to be situated on the wall of the vessel, extending possibly some distance along its coat. We regard this as a protective manifestation rather than as the evidence of a virulent process. Test-puncture is *not* recommended in such cases, and in the absence of distinct, physical, local, and constitutional symptoms, no surgical interference should be attempted.

Furthermore, as *Jansen*, *Heine*, *Kerrison* (18), and others have held, the granulations found upon the sinus wall are to be regarded as protective agents and should not be removed. The increased rigidity and the consequent absence of pulsations may be due to these protective granulations.

The procedure advocated in such cases is to wait, first removing all diseased bone and detritus. In the great majority of cases, recovery usually follows without further incident. We hold it a technical error either to puncture the blood-vessel in such cases, or to open the sinus wall to examine its interior, and we take exception to the standpoint of *Richards* (19), and *Leutert*, who advocate such procedures, even in cases where the sinus is only under suspicion, and fails to give distinct symptoms of septic involvement.

On the other hand, compression thrombi, situated along the wall of the sinus, when giving systemic symptoms—chills, fever, headache, pain in the region of the jugular—are to be considered in another category; these demand inspection and prompt surgical attention. Here puncture may be tried, although it has usually been found unsatisfactory. Incision and inspection of the interior of the vein are indicated. We will revert to the technique below.

Upon exposure of the vessel's wall the obstructing, infectious type of sinus thrombosis is readily recognized. The vessel is found to be hard and full and usually incompressible. It may be covered with granulations, or its walls will be found very thin and infiltrated with purulent inflammatory exudate. I saw cases where the walls had been completely destroyed by the purulent process, there being no evidence of the lumen of the blood-vessel, only its posterior wall covering the brain remaining intact. The interior of the vein was exposed and formed part of the pus sac which was shut off from the torcular and the bulb by the remains of the original thrombus. In many cases the picture presented is not as distinct as that just described; in many cases the character of the lesion is obscure, and it is in these doubtful cases that test puncture, or better still, exploratory incision of the vein settles the diagnosis.

This type of sinus thrombosis usually gives rise to the typical systemic symptoms of vomiting, fever and chills, with the characteristic rapid fall of the temperature curve, accompanied by sweating; the cycle of chills, fever, and drop in temperature, with sweating frequently recurring twice or oftener in twenty-four hours. Metastases bring in their train their characteristic

symptom complex. For a detailed discussion of the symptomatology of sinus thrombosis, the reader is referred to text-books dealing with this subject.

Surgical Signs Pointing to Thrombosis: In sinus thrombosis, œdema at the posterior edge of the mastoid process from occlusion of the mastoid emissary vein; and even the formation of subperiosteal abscesses have been observed (*Griesinger*, 20). Infiltration of the muscles of the neck has also been observed. According to *Körner* (16), this points to perisinus abscess rather than to sinus thrombosis of the lateral sinus. *Gerhardt* (21), and *Petrenz* (22) have observed an inequality in the feel of the jugulars of the two sides in cases of thrombi occurring among marasmic children. In thrombus, *Voss* (23) fails to hear the bruit of the blood passing through the affected jugular; a sign which *Körner* has verified.

The stethoscope should be placed rather high on the neck, and the sound heard should be compared with that found over the carotids.

The appreciation of the presence of a strand or string in the neck when the jugular is thrombotic is a common observation. *Jansen* (24) and *Schwartze* (25) contend that pain in the jugular region, without swelling or without finding a cord-like strand along the site of the vein, is evidence of absence of disease in the jugular. It should be remembered, however, that the thrombosed jugular cannot always be palpated. The posture of the head is often characteristic, however. The patient holds the head steadily fixed toward the diseased side, and endeavors to avoid all motions of the head because of the attendant pain.

Finally, we have physical signs from the concomitant involvment of regional nerves; thus hoarseness, aphonia and dyspnœa are reported, due to compression of the vagus. *Kessell* (26), *Stacke* and *Kretschmann* (27), and *Schwartze* (28); while *Beck* (29) has observed death through paralysis of the vagus. Retardation of the pulse; spasm in the sterno-mastoid (*Wreden*, 30), and hypoglossal paralysis have been observed (*Beck*, *Kessel*). Painful swelling in the neck from thrombosis of the venæ emissariæ condyloideæ are reported by *Macewen* (13). Oedema of the eyelids, with phlebitis of the ophthalmic veins and

hyperæmia of the retina and optic neuritis, and occasionally retrobulbar œdema with exophthalmos or orbital phlegmon, either together or in any combination, are suggestive of thrombosis of the cavernous sinus. Neuralgias of the first branch of the trigeminus and paralysis of the abducens, the trochlearis and the oculo-motor are likewise often significant of involvement of the cavernous sinus.

Summarizing the surgical signs of sinus thrombosis, we find that they consist of symptoms referable to the involvement of veins external to the skull, and signs of injury to nerves which emerge from the skull with the sinus through the jugular foramen.

The interpretation of these signs with the clinical symptoms give the indications for operation on the diseased sinus.

Indications for Employing Test-puncture of the Lateral Sinus: The main value of the test-puncture is a diagnostic one. When a sinus has been exposed during mastoid operation, and has either been the seat of a perisinus abscess, or when the vessel's walls show discoloration or purulent infiltration, with absence of pulsations; or when they are found hard to the touch and covered by granulations which are easily wiped off; and when, with such findings, fever not only persists after mastoid operation, but takes on a pyæmic curve, unaccounted for by any other lesion, then suspicion is rightfully directed toward the discolored sinus. A puncture of its walls with a sterile needle attached to a suitable syringe is indicated under these conditions, to obtain information as to the condition of the interior of the veins.

Only *positive findings* from the puncture are of practical importance; negative findings—the demonstration of fluid blood in the vein—do not rule out sinus thrombosis. The puncture may be negative because the needle has penetrated beyond the thrombus. This is easily conceivable if the thrombus is located on the sinus wall. It may also be negative because the thrombus lies centrally, surrounded by fluid blood, or because the thrombus is located at a point different from that reached by the needle, as when the thrombus is located at the jugular bulb and the needle is introduced at some point nearer the sinus knee. Finally, after the disintegration of a thrombus, the blood channel

is re-established, and fluid blood may be withdrawn and a negative result obtained which naturally is of no diagnostic value.

Furthermore, the failure to procure fluid blood may, in rare instances, be due to the failure of the needle to penetrate the entire thickness of the sinus walls, or the needle may have penetrated beyond the opposite sinus wall. This latter contingency must be guarded against especially when puncturing in the region of the tentorium cerebelli. The finding of pus or purulent blood is of diagnostic value. No diagnostic data is to be adduced from a dry puncture.

Dangers of Test-puncture : The danger of infecting a healthy sinus should be borne in mind when it is unnecessarily punctured. *Green* (31) reports a case where a thrombus was found at the puncture point, following a test-puncture. The use of the puncture carries with it the danger of dislodging a thrombus, and dislodging particles which pass into the general circulation. Hence, the puncture should never be undertaken except where the signs and the symptoms are so marked that the surgeon is prepared to proceed at once to the opening of the sinus and the eradication of the thrombus.

Indications for Opening the Sinus : Where suspicion is aroused by the post-operative persistence of temperature, the advent of headache, etc., whether the operation in question was the simple or the radical mastoid; and where the symptom complex is otherwise unexplainable—a test-puncture failing to furnish additional diagnostic data—then the incision of the sinus is indicated to establish the diagnosis of thrombus. Where the findings are positive we clean out the infected accumulation from the vessel.

Where during the performance of mastoidectomy, the destruction of bone has extended to the inner table and has exposed the sinus wall, bathing it in the purulent contents of the mastoid cavity, or involving the sinus in a perisinus abscess; and where the evisceration of the diseased bone and the cleansing of the wound cavity is not followed by the prompt cessation of pyæmic symptoms—then the opening of the suspected vessel is indicated.

Furthermore, in cases where a perisinus abscess is uncovered, and is found to involve the integrity of the vessel wall, or to have destroyed the wall, and where the sinus itself is open and

contains pus, shut off above and below by obstructing thrombi, then the cleansing of the open sinus is indicated, with ligature or resection of the jugular, as the condition presented may demand.

When a sinus is either uncovered, or is found upon exposure to be hard, non-pulsating, almost incompressible and discolored—then the opening of the implicated vessel is indicated, if septic symptoms persist for any length of time (usually beyond twenty-four hours) after the performance of mastoidectomy.

In all these cases, except possibly where we find the vessel opened by the purulent process, we first perform the mastoid operation, and then await the clinical development of the case.

We do not advocate *immediately* opening the sinus upon mere suspicion, but only when we have clinical symptoms of sepsis pointing to the sinus, which persist after mastoidectomy has been performed. As *Körner*, *Heine* and others point out, many cases exhibiting distinct pyæmic symptoms recover without operation upon the sinus, even when perisinus abscesses are present, an observation which we have seen verified in cases under our care.

We cannot agree with *Richards* (19) who advocates opening the sinus regardless of the appearance, of the feel or the pulsations of the vessel, when symptoms of septic absorption are present, but the involvement of the sinus as the cause of these symptoms is only surmised. Nor do we agree with him when he advocates the opening of the vessel after exposure upon mere suspicion. Were we to accept the one proposition, we would unnecessarily open many a healthy sinus, and to operate without symptoms, upon mere suspicion, is not conservative surgery.

To summarize, we open the sinus:—

1. When evidence of a disintegrating thrombus is presented by the symptom complex, and when the test-puncture is negative, with persistence of symptoms referable to the sinus;

2. In cases where the sinus wall is destroyed to a greater or a lesser degree and where possibly some of the clot is still *in situ;*

3. In the presence of repeated chills, septic temperature, and a poor physical condition of the patient, otherwise unaccounted for, with a suspicious-looking sinus wall;

4. In the presence of optic neuritis (not a certain indication).

The symptom complex must govern the surgeon's judgment. There is no hard and fast rule for all cases; the procedure must be made to fit the findings in each case.

We will revert below to the question of ligature of the jugular.

Contraindications for Opening the Sinus: In cases where severe sepsis or toxæmia is present surgery is almost hopeless; nor will the opening and the removal of the clot be of much avail where severe and extensive meningitis already is present. When metastases have involved the lungs, there is small chance of recovery.

On the other hand, in spite of the above, the surprising record of many cases—whose published histories show the desperate straits to which the patients were reduced and from which they recovered after operation upon the sinus—has encouraged surgeons so much that the operation is tried on all cases, no matter how desperate, in the hope of securing an unexpected recovery. In such cases, the chances of recovery are small.

Indications for Ligature or Resection of the Internal Jugular: When secondary to mastoiditis, unmistakable signs of infective sinus thrombosis supervene, and the evidence presented is such that we conclude that the infected thrombus has either undergone disintegration or is threatened with disintegration, then the exposure and the eventual ligation of the internal jugular vein are indicated. If, in addition, the jugular vein is thrombosed, giving, upon palpation, the feel of a hard cord-like strand and terminating gradually at its lower end until this feel is lost—an evidence of descending disintegration of the thrombus in the jugular vein—then the resection of the diseased section of the vein is indicated.

In each instance, the sigmoid sinus must be immediately opened, lest the thrombus spread toward the torcular, the petrosal sinus, or the cavernous sinus. This is the general principle. The mode of procedure is modified by the conditions governing each individual case.

The resection or the ligature of the jugular vein is recommended in all cases of sinus thrombosis by *Leutert* (32), *Schencke* (33), *Grünert* (34), *Viereck* (35), and *Zaufal* (36), who usually tie off

the jugular vein before they open the sinus. Contrary views are held by *Jansen* (37), *Brieger* (38), *Körner* (16), *Richards* (39), and others.

The time during the operation at which to ligate the jugular vein is a mooted question. The authorities cited above recommend that the vein be ligated as soon as the diagnosis of septic thrombosis is made, usually before the sigmoid sinus is opened. The reasons given are mainly—to prevent emboli from passing into the general circulation (*Grünert*); because of the impossibility of absolutely establishing the presence of an obstructing clot below the bulb (*Leutert*), and because there is danger of detaching fragments which will pass into the general circulation while the surgeon is working upon the sigmoid sinus (*Schenke*).

On the other hand, *Heine* (40) recommends the opening of the sinus in the first place, with removal of the thrombus, reserving the ligature of the jugular for special cases. He then advocates expectant treatment to await the outcome of the removal of the thrombus, even in cases where the central end of the thrombus proves to be inaccessible. He ties the jugular vein only when severe pyæmic symptoms persist after the removal of the thrombus from the sinus. *Körner* holds the ligature of the jugular vein justified in all cases of thrombosis, even if no pyæmic symptoms supervene.

The position held by the thrombus is of importance in determining whether to tie the jugular vein prior to, or after, opening the sinus. Thus if the thrombus is located in the bulb, and exposure of the sigmoid and the application of *Whiting's* Test* show the thrombus to be at, or below, the bulb, then ligature of the jugular is indicated before the sinus is opened.

Commenting upon the difficulty of making a positive diagnosis of the lower limit of the thrombus prior to opening the

* Whiting's Test (41): The index finger is placed across the sinus at the bulb (which is exposed) with sufficient firmness to cause obliterative pressure upon the walls at this point. The other index finger is then placed beside the first one, and with a stripping motion passed along the vessel's course toward the torcular as far as the exposure permits. Firm pressure is now made by an assistant upon the jugular vein low down in the neck, producing a backward blood pressure toward the bulb.

It is obvious that were an obstructing thrombus present in either the jugular vein or the sinus, that the collapsed walls of the sinus would not bulge because of blood distention when the lower index finger is removed. If they do bulge, then presumably no obstructing thrombus is present.

sinus, *Richards* calls attention to the possibility of unnecessarily ligating or resecting many jugulars, when we perform the operation on the jugular before the sinus is opened. After slitting the sinus wall as far as possible toward the bulb he proceeds to the jugular resection if he fails to produce a spontaneous flow, or if the flow of blood is found to be insufficient. He does not attempt to curette the thrombus from the bulb before the work on the jugular vein is completed. His reasons for not disturbing the clot in the bulb prior to jugular resection are the dangers which result from detached fragments, and also because of the anatomical difficulties presented by the bulb to curettage from above (39).

A thrombus whose position is unmistakably defined, and which lies well up above the bulb, can be completely removed without resorting to jugular resection or even ligature. Bearing in mind the findings of *Jansen*, *Brieger*, *Preysing* (42), *Richards*, and others, we formulate the indications for jugular resection as follows, endeavoring to classify and group the cases so as to point out the times when surgical intervention on the jugular is indicated.

Indications for Jugular Ligature (Resection) Before, At, and After the Sinus Operation:

I. The ligature and the resection of the jugular are indicated *before* mastoidectomy:

(*a*) In cases which come under observation late and present a symptom complex of septic pyæmia, accompanied by an infiltration along the course of the jugular vein, which is painful upon manipulation;

(*b*) In cases with a symptom complex of septic pyæmia which accompanies an acute or chronic mastoiditis, and where the examination reveals a distinct, hard cord-like band in the locality of the jugular. The stethoscope placed over the vein fails to give the bruit, and all physical signs point to an extensive involvement of the jugular vein;

(*c*) In cases of grave sepsis (septic otitic pyæmia) wherein demonstrable pyæmic metastases are present;

(*d*) In cases where the positive diagnosis of jugular phlebitis or primary bulbar thrombosis is possible.

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On the other hand, *Heine* (40) recommends the opening of the sinus in the first place, with removal of the thrombus, reserving the ligature of the jugular for special cases. He then advocates expectant treatment to await the outcome of the removal of the thrombus, even in cases where the central end of the thrombus proves to be inaccessible. He ties the jugular vein only when severe pyæmic symptoms persist after the removal of the thrombus from the sinus. *Körner* holds the ligature of the jugular vein justified in all cases of thrombosis, even if no pyæmic symptoms supervene.

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The position held by the thrombus is of importance in determining whether to tie the jugular vein prior to, or after, opening the sinus. Thus if the thrombus is located in the bulb, and exposure of the sigmoid and the application of *Whiting's* Test* show the thrombus to be at, or below, the bulb, then ligature of the jugular is indicated before the sinus is opened.

Commenting upon the difficulty of making a positive diagnosis of the lower limit of the thrombus prior to opening the

* Whiting's Test (41): The index finger is placed across the sinus at the bulb (which is exposed) with sufficient firmness to cause obliterative pressure upon the walls at this point. The other index finger is then placed beside the first one, and with a stripping motion passed along the sinus in course toward the torcular as far as the exposure permits. Firm pressure now made by an assistant upon the jugular vein low down in the neck, producing a backward blood pressure toward the bulb.

It is obvious that were an obstructing thrombus present in the jugular vein or the sinus, that the collapsed walls of the sinus, because of blood distention when the lower index finger is removed, do bulge, then presumably no obstructing thrombus

sinus, *Richards* calls attention to the possibility of unnecessarily ligating or resecting many jugulars, when we perform the operation on the jugular before the sinus is opened. After slitting the sinus wall as far as possible toward the bulb he proceeds to the jugular resection if he fails to produce a spontaneous flow, or if the flow of blood is found to be insufficient. He does not attempt to curette the thrombus from the bulb before the work on the jugular vein is completed. His reasons for not disturbing the clot in the bulb prior to jugular resection are the dangers which result from detached fragments, and also because of the anatomical difficulties presented by the bulb to curettage from above (39).

A thrombus whose position is unmistakably defined, and which lies well up above the bulb, can be completely removed without resorting to jugular resection or even ligature. Bearing in mind the findings of *Jansen*, *Brieger*, *Preysing* (42), *Richards*, and others, we formulate the indications for jugular resection as follows, endeavoring to classify and group the cases so as to point out the times when surgical intervention on the jugular is indicated.

Indications for Jugular Ligature (Resection) Before, At, and After the Sinus Operation:

I. The ligature and the resection of the jugular are indicated *before* mastoidectomy:

(*a*) In cases which come under observation late and present a symptom complex of septic pyæmia, accompanied by an infiltration along the course of the jugular vein, which is painful upon manipulation;

(*b*) In cases with a symptom complex of septic pyæmia which accompanies an acute or chronic mastoiditis, and where the examination reveals a distinct, hard cord-like [illegible] of the jugular. The stethoscope placed over the [illegible] give the bruit, and all physical signs point to involvement of the jugular vein;

(*c*) In cases of [illegible] sepsis (septic [illegible] demonstrable pya[illegible]stases [illegible]

(*d*) In [illegible]

the jugular vein before they open the sinus. Contrary views are held by *Jansen* (37), *Brieger* (38), *Körner* (16), *Richards* (39), and others.

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(*b*) In cases with a symptom complex of septic pyæmia which accompanies an acute or chronic mastoiditis, and where the examination reveals a distinct, hard cord-like band in the locality of the jugular. The stethoscope placed over the vein fails to give the bruit, and all physical signs point to an extensive involvement of the jugular vein;

(*c*) In cases of grave sepsis (septic otitic pyæmia) wherein demonstrable pyæmic metastases are present;

(*d*) In cases where the positive diagnosis of jugular phlebitis or primary bulbar thrombosis is possible.

In these cases there is an imperative demand for promptly shutting off the general circulation from the source of infection. The danger resulting from a possible spread toward the cranium is manifestly less than the risk incurred by overwhelming the general system with infectious material circulating in the blood. The mastoidectomy is performed as soon after the jugular resection as the patient's condition will permit.

II. The resection or the ligature of the jugular vein is indicated *after* mastoidectomy and after *exposure* of the lateral sinus:

(*a*) In cases in which the sinus wall appears healthy, and no perisinus abscess was found at the time of mastoid exenteration, but where, nevertheless, inexplicable chills, with rise and fall of temperature—the clinical picture, in other words, of severe pyæmia are present. In these cases, the sinus should be tested by puncture to locate the clot, and if the test fails, then the sinus should be opened, its interior explored *before* the jugular vein is resected. If upon opening the sinus, the flow from both ends is free and spontaneous, then the presumption exists that no thrombus is present; on the other hand, failure to get a flow from the jugular end indicates ligature and eventual resection of the vessel;

(*b*) In cases of periphlebitis, which in the presence of a parietal (wall) thrombus, gives severe septic symptoms, manifestly due to septic material which becoming detached, has entered the general circulation.

III. The resection or the ligature of the jugular vein is indicated *after* the *sinus* has been *opened:*

(*a*) In cases in which the opened sinus shows a thrombus whose bulbar end is inaccessible;

(*b*) In cases where the septic thrombus lies in the bulb;

(*c*) In cases where a thrombus located in the jugular bulb has undergone disintegration;

(*d*) In cases where the sinus appears normal, but in which the local findings are such as to signify jugular thrombosis. In this class of cases, after opening the sinus, the operation on the jugular is to be completed *before* cleansing out the sinus (*Richards*, 39).

IV. Finally, the operation on the jugular vein is indicated *after* the sinus is opened:

(*a*) In cases in which the symptoms of pyæmia do not promptly subside after the apparent complete removal of a thrombus, which was located at some point above the bulb;

(*b*) In cases wherein an opening was made accidentally in the sinus during the performance of mastoidectomy, and where subsequently pyæmic symptoms supervened which did not promptly subside after exploration of the wounded sinus;

(*c*) In cases in which exposure and opening of the sinus failed to discover a thrombus, and in which, after a variable length of time, symptoms of pyæmia come on either with or without recognizable metastases. In this group of cases, after all other lesions have been eliminated by careful differential diagnosis, the operation on the jugular vein is in order, on the presumption that an undiscovered thrombus is located partially in the bulb, or in one of its tributary veins. In this connection, it must be borne in mind that fever and chills often remain for some time after a sinus has been relieved of its thrombus. In fact, *Jansen* reports observing the persistence of both fever and chills for some time after jugular ligature. In conclusion, the indications calling for jugular resection, rather than simple ligature, often depend on the condition of the vein as we find it at the time of operation.

We believe it safer to remove as much as possible of the cardiac portion of the vein, because the vessel wall itself is often infected; this is not observable macroscopically. We do not wish to leave a septic strand of useless tissue *in situ*, from which other contributary veins may become infected. The slightest suspicion of actual involvement of the vein indicates its complete removal.

The Operation of Exposure of the Sinus: If, during the performance of mastoidectomy, indications are found directing our suspicion to the sinus, we continue the evisceration of the mastoid contents toward the sinus.

As the hard tablet of bone covering the sinus is reached, it is carefully smoothed with the sharp curette, and finally the bony covering of the vessel is carefully broken through at a point,

preferably near the knee. For this purpose we use a broad, rounded but flat chisel. The opening is carefully enlarged so as to permit the introduction of the small beak of a rongeur under the bone, between it and sinus wall; with this the bony covering is easily removed for the desired distance upward and backward, as well as downward and forward toward the bulb.

In using the rongeur, only small bites should be taken in the bone, and in breaking off the pieces, pressure should be exerted away from the sinus wall. The pieces should not be broken away in such a manner that the end of the instrument impinges on the sinus, or presses into it at each bite, nor should the bone be so grasped that the osseous particles press on the vessel wall. In any of these contingencies, injury or actual laceration of the sinus wall may result.

Many surgeons prefer the spoon curette to the rongeur for this maneuver, a small, rather flat curette serving their purpose. In the use of the curette, the same care should be exercised not to pinch the sinus wall, and not to tear and lacerate it with the bone fragments as when using a rongeur. In Europe, many surgeons employ a flat chisel, rounded at the end; the chisel devised by *Lucae* best answers the purpose.

With reasonable care, the free exposure of the sinus presents no difficulties and is easily and rapidly accomplished. When attempting exposure down to the bulb the danger to the facial nerve must be remembered, as the nerve crosses the sinus at the bottom of the posterior meatal wall. The exposure of the sinus backward toward the torcular presents no danger points, although occasionally the mastoid emissary vein is injured and bleeds profusely.

When the sinus has been exposed, its appearance, its feel, and its color are subject to examination. We note the presence or absence of discolorations, granulations, and pulsations.

If the vein is not opened, we proceed to finish the mastoid surgery, and in dressing the cavity, we cover the exposed sinus with a separate strip of iodoform gauze, taking special care that the packing in the mastoid wound does not compress the vessel in any way. Performed in this careful way, the exposure of the

sinus involves practically no danger at all. The most important point to be borne in mind is the absolute removal of all splinters of bone. If any particles of bone remain between the bony casement and the soft wall of the sinus, they act as foreign bodies and may subsequently cause trouble.

During the after-treatment, especial care must be taken not to injure the sinus wall in changing the dressing. The exposed sinus rapidly becomes covered with granulations, which coalesce with those arising from other parts of the wound cavity. The remainder of the after-treatment is carried out in a manner similar to that described in the after-treatment of the radical mastoid.

The Opening of the Sinus : The sinus is exposed as described above and the exposure is extended to uncover fully and freely the area which is suspected of containing the thrombus. The bone surgery of the remainder of the mastoid process is completed as rapidly as possible. When a small section of sinus which shows a healthy color has been reached beyond the diseased area, a small plug of iodoform gauze is inserted between the bone and the soft sinus wall, completely compressing the vessel. This controls the hemorrhage from the distal (torcular) end. The exposure toward the bulb is now carried out, and when a sufficient exposure has been effected, a similar gauze plug is here introduced, shutting off the lumen of the vessel centrally.

The exposed area between the two plugs is now incised and emptied of thrombus and blood. Very little hemorrhage follows if the two plugs have been correctly inserted. If the thrombus thus removed appears dark red or brown, and is found to be of hard consistency, it is not a disintegrating thrombus; and if the exposed area of sinus which has thus been opened is found to extend beyond the limits occupied by such a thrombus, we may presume that the obstruction has been completely removed.

A test of the blood-current above and below now follows. Carefully plugging off the lower wound parts, the plug of gauze placed at the torcular end of the sinus exposure is cautiously withdrawn, and if all the obstruction has been removed from

this end, a spontaneous blood flow is at once apparent; this is soon checked by the replacement of the first plug. The blood-soaked packings are now changed, and the maneuver is repeated by the cautious withdrawal of the plug at the bulbar end of the opened sinus. If a spontaneous, free flow of blood ensues, the operator rests his procedure by replacing the plug.

The opened sinus is now washed with a solution of bichloride of mercury (1:3000), and the wound cavity packed as already described. The obstructing plugs at both torcular and bulbar ends of the opened sinus remain in place for a week or ten days, and are then cautiously withdrawn and replaced only if hemorrhage follows their removal.

If the opened sinus reveals a clot which is of a dirty green or a yellow color, or if the clot is gray or very black, and of a soft consistency, or while dark and hard in its central portion, tapers off at its central end to a dirty gray or yellow, or if the central end is not in view, and the removal of the plug from the central end fails to bring on a spontaneous flow of blood, then a temporary packing of the mastoid wound is indicated and the exposure and ligature of the jugular vein should be undertaken, before any instrumentation is carried out to remove the centrally located portion of the thrombus. We deprecate the introduction of either curette, probe, or other instrument into the opened sinus toward the bulb, for fear of dislodging fragments into the general circulation.

The Resection of the Jugular: The wound in the mastoid having been temporarily covered with sterile dressings, the neck is placed upon the stretch and scrubbed and cleansed with green soap, alcohol, ether, and bichloride of mercury solutions. In sterilizing this field of operation, the neck should not be unnecessarily kneaded. *Richards* advocates grasping the skin and lifting it from the underlying tissue, so as to prevent disturbing the contents of the vessel during these manipulations.

The vein is exposed by an incision placed along the anterior border of the sterno-mastoid muscle. The incision is best made with a sharp bistoury and carried from the level of the hyoid bone, often beginning some distance above it, down to the clavicle. Bleeding points are rapidly clasped and the dissection con-

tinued through the platysma myoides and cervical fascia to the sheath of the vessel. In incising through the neck fascia, care must be exercised not to pull on the skin or fascia, as then the incision will tend to leave the region of the anterior border of the sterno-mastoid muscle. Tributary veins are lifted clear of the surrounding fascia, and severed between two ligatures previously thrown about them.

As the upper belly of the omohyoid is reached, we cut through it and push it aside. We have never observed any ill-effects to follow this procedure. The internal jugular vein is finally uncovered lying in the sheath with the carotid artery and the vagus nerve. The later is situated between and behind both these vessels. The jugular vein is freed from the surrounding tissue and ligated as low down in the neck as possible. If feasible, the lower ligature should be thrown about the vessel as soon as its lower part is exposed, to prevent loosened fragments of clot from entering the circulation during the manipulation of the parts. The upper ligature is placed as high and as near the bulb as we conveniently can reach (if, possible, above the facial vein). All anastomotic branches are now ligated, and the jugular vein is resected by removing the entire length of the exposed portion, whether a thrombus is found in it or not.

We advocate the resection rather than the simple ligature of the jugular, as the vessel wall is in itself a carrier of infection, and spreads the disease to the general circulation through the anastomosing branches of the vein.

The jugular having been resected, a gauze drain is pushed upward toward the bulb, then the external wound is loosely packed with gauze, and a few purse-string sutures are passed through the integument. These sutures are not drawn tightly together, but are used to approximate the edges of the skin and the fascia over the drainage gauze. At subsequent dressings, if conditions are favorable, these edges are gradually pulled together until they finally become adherent, thus leaving less of a disfiguring scar. The external surface is covered with gauze and an outer dressing is applied; primary union of the cervical wound should not be attempted.

Before this is done, the distal stump of the jugular, i.e., the

portion leading to the bulb, requires attention. Some surgeons flush the jugular bulb by introducing the nozzle of a syringe into the vein and washing through to the sinus, or vice versa. We consider this a technical error, as by such a procedure particles of the thrombus may be forced into the collateral venous branches and septic particles disseminated through the system. The temporary dressings are now removed from the mastoid cavity and the end of the sinus toward the bulb is cleared out; a suitably curved curette being used for the purpose.

The removal from the bulb of as much of the clot as will come away by this procedure is all that is necessary. We then flush the parts with bichloride of mercury solution; not finding it necessary to wash through to the jugular stump.

A gauze drain is introduced into the bulb, extending into the outer dressings. The mastoid wound is lightly packed and dressed as already described. The plug at the torcular end remains in place for from eight to ten days, and is completely removed only when no hemorrhage is apparent at its displacement.

Occasionally pus is evident from the bulb end of the sinus, or in the jugular stump for a length of time, but this gradually disappears in cases which are progressing favorably. Efforts to close the neck wound follow the subsidence of the suppuration at the bulb. The after treatment of the mastoid wound is but slightly affected by this additional procedure. The wound is permitted to close by granulations as the suppuration in its interior subsides.

In an effort to convert the sinus, the bulb, and the jugular vein into one continuous groove, having a common external opening, some surgeons completely obliterate the bulb. *Grünert* (43), who advocates this procedure, recommends it where bulbar thrombosis cannot be satisfactorily treated from either above or below the bulb. Our experience has shown such a condition to be rare. It is always possible to reach the bulb from above and the small amount of septic material left behind in a stump shut off from the general circulation soon discharges itself into the neck wound in a patient whose condition is not already so profoundly septic that recovery is impossible.

In cases progressing favorably, we tighten the purse-string sutures daily, and sometimes approximate the lips of the neck wound, and thus hasten healing. Once we succeeded, under cocaine-anæsthesia, to close the wound in the neck entirely on the fourth day.

Dangers Presented: The dangers of resection of the jugular are not to be considered in the light of the recoveries which result from the operation. Aspiration of air, or dissemination of septic emboli during the manipulations, are avoidable by placing the lower ligature deeply down in the neck as early as possible in the operative procedure. The dangers of local neck infections are to be considered, but with reasonable antiseptic precautions these are preventable. Accidental injury to other structures is guarded against by a thorough mastery of the surgical anatomy of the region in which we are operating. Care is necessary to avoid including the vagus in the ligation of the jugular. Dissemination of emboli, or air aspiration in contributary branches, is avoidable by placing double ligatures on all vessels, between which they are divided.

As we approach the jugular bulb from the sinus side, the danger of injuring the facial nerve where it crosses the sinus must be kept in mind. Injury to this nerve is not always avoidable. During the removal of the tip of the mastoid, working toward the bulb near the insertion of the digastric, the nerve may be injured as it emerges from the stylo-mastoid foramen.

Circulatory disturbances have rarely been observed to follow ligature of the jugular. Disturbances in the circulation of the brain have been reported by *Linser* (44), and by *Rohrback* (45).

After Effects: After the removal of the infected jugular and the cleansing out of the sinus, we expect a prompt cessation of the pyæmic symptoms, a result usually obtained in uncomplicated cases. Occasionally the fever persists for a few days longer, and *Jansen* (l. c.) has observed the continuance of both chills and pyæmic temperature for some time after jugular resection; this has been due to toxæmia.

The continuance of high temperature, or its recurrence after a period of cessation, must always be regarded with suspicion, either of the development of metastatic lesions from foci infected

prior to the removal of the clot, or of the development of new complications (brain abscess, meningitis, etc.). In this regard, a case recently under my care teaches a lesson:

A female, eighteen years of age, was operated upon for an acute exacerbation of a chronic middle ear suppuration, and at the mastoidectomy, a perisinus abscess was discovered which had invaded and entirely destroyed the sigmoid portion of the lateral sinus. The sinus wall was eroded and presented a large irregular opening, from which pus flowed freely without pulsation; this orifice communicated with the purulent disintegrated interior of the mastoid. Obstructing thrombi at the bulb and near the torcular shut off the circulation of blood in the vessel. Because of her septic appearance, high fever (105° F.)—as soon as the local condition was observed—jugular resection was resorted to before any attempt was made to remove the clot from the bulb. The jugular vein was successfully removed. It was found collapsed, almost free of blood, without macroscopic evidence of infection of its walls, and no thrombus was located within the vessel.

The lateral sinus was traced backward to within one-half inch of the torcular, before the obstructing thrombus at that end was reached and removed and a free blood flow obtained. After cleansing the wound and eviscerating the contents of the mastoid, and finishing the radical mastoid operation, the wounds, both in the neck and in the mastoid region, were packed.

The operation was well borne and the patient continued to improve, the temperature dropping to normal. Both neck and mastoid wound cleaned up within a week and the patient was permitted to leave her bed and take full nourishment. Toward the end of the tenth day, the wound gradually became foul, in spite of repeated antiseptic dressings, and the patient's general condition began to grow worse. The temperature rose to 101°-102° F., and a search for the cause of the trouble was made. See Chart VIII.

The eye discs gave evidence of a slight blurring on their temporal sides, but this was not sufficiently marked to be significant. Some lateral strabismus was present, to which, in a few days, nystagmus was added. There was some staggering in the gait, but no dizziness or muscular twitchings or vomiting. This

condition continued, and an exploration of the wounds was made fourteen days after the mastoidectomy and jugular resection, under general anæsthesia.

The dura over the cerebrum and cerebellum was uncovered and found to be of healthy color and normal in every way. The middle ear cavity was examined, and nothing to account for the gravity of her condition was found. The region of the bulb, both from the mastoid side and from the neck side, received attentive examination, but no findings of diagnostic value were obtained.

The patient recovered from the exploratory operation, and the disease ran an uninterrupted course for five days longer, with continued nystagmus, and pain beginning at the back of the head. At the frequent changes of dressings, the exposed dura showed nothing abnormal, and the patient's mental condition to within two days of her death, remained clear. At this time the temperature ranged between 100°–102° F. Examination of the ocular fundus now revealed blurring of the disc in the right eye, and inequalities of the pupils.

The patient died suddenly on the nineteenth day after mastoidectomy, that is, five days after the exploratory operation. While no post-mortem was performed, a local examination demonstrated a subdural abscess, from which pus exuded after death. The pus seemed to come from the subdural space below and behind the position occupied by the knee of the sigmoid sinus; the intervening dura had exhibited no pathological indications of its being the covering of an abscess. Thus an undiscovered cerebellar abscess was demonstrated. We cite this unfortunate case to impress the gravity of the persistence of temperature or other symptoms after the removal of septic thrombi from the lateral sinus.

In conclusion, unless the after-effects immediately furnish evidence of uninterrupted improvement, or the symptoms point to a condition of general sepsis or metastatic foci, then search should be made for intradural, cerebral, or cerebellar abscesses, even if the superficial meninges show no signs of pathological changes or no increase in the intracranial pressure is demonstrable.

Obstacles to the Operation on the Jugular: Obstacles to the easy performance of the resection of the jugular may be present in the form of local œdema of the neck, purulent infiltration into the cervical tissues; regional glandular swelling, and abscesses of the neck. In the literature, five cases are reported where the diseased jugular was not discoverable (twice not even demonstrable at the autopsy; (39),) *Markins*, (46). *Schwartze* (47), *Körner* (48), *Barnik* (49), *Schenke* (50), *Knapp* (51), and *Muck* (52) report having experienced trouble in finding and recognizing the collapsed cord-like vein.

Results of Various Procedures: The simple exposure of the sinus to examine its coat has little or no bearing on the future course of the case, provided the vascular coat is uninjured and the tampons do not compress its lumen during the after-treatment. The opening of the sinus to explore its interior and search for thrombi, if performed under aseptic precautions, likewise plays but a small part in influencing the final outcome of the case. In those cases where the thrombi are situated well up away from the jugular bulb and removed, the patients usually recover. The report of *Heine* (53) on ninety cases wherein an actual thrombus was discovered in each case is as follows:

Sixteen died of intercurrent disease in no way referable to the thrombotic vessel; of the remaining 74 cases, 36 recovered. Six of the recoveries and eight of the deaths were cases in which the jugular was ligated; that is, of the uncomplicated cases, 48.5% recovered.

Körner (54), estimating the results from 308 operated cases, finds 180 recoveries and 125 deaths, and 3 whose history was incomplete. I republish his table of results at the top of page 234.

Finally, in view of the almost universally fatal outcome of the unoperated cases, the operation should always be considered as a means of possible relief. In view of the many recoveries which have followed the operation in cases which were thought to be hopeless, this is justified.

Untoward Sequelæ: Untoward sequelæ are uncommon. *Linser* (44) noted œdema of the brain, ending in death after ligature of the jugular, and *Rohrback* (45) likewise makes report

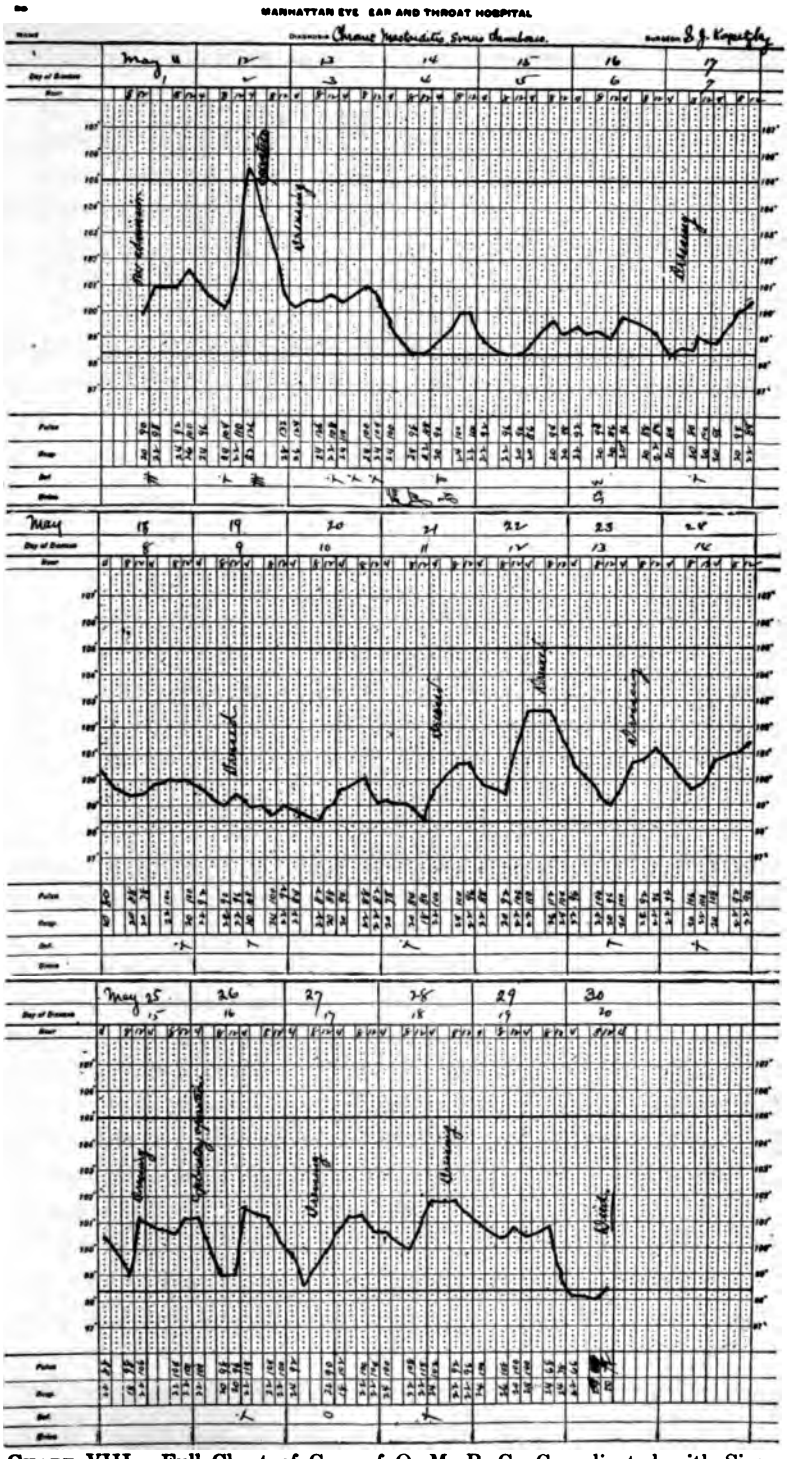

CHART VIII.—Full Chart of Case of O. M. P. C., Complicated with Sinus Thrombosis (Jugular Resection) and Terminating Fatally from Brain Abscess. (See page 230-231.)

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s space is rather unevenly dis-
At places it is scarcely demon-
le in other brain sections (pos-
presents itself as a wide interval
achnoid. The widest part of this
, pons and interpeduncular recess,
considerable interval is noted pos-
um and the medulla oblongata, and
evident above the corpus callosum.
ched across below the falx cerebri.
e, the subarachnoidal space is in com-
ricles of the brain. Th there is no
annel between the sub the sub-
fluid can pass through
dural space (*Macewe*

Operation	Number of Cases	Result Doubtful	Death	Cured	
Ligature of jugular without opening sinus.....	9	0	4	5	
Sinus opened without ligature of jugular.....	132	0	55	77	−58.3%
Ligature of jugular (or resection) *before* opening sinus.....	94	2	36	56	−59.6%
Ligature of jugular (resection) *after* opening sinus.	68	1	29	38	−55.9%
Ligature of jugular and sinus opened, but not stated in what order.....	5	0	1	4	
Totals:	308	3	125	180	−58.4%

Cf. p. 222.

of similar findings. *Richards* reports having seen obstructed venous return circulation in two cases. In one, there was evident papillitis in the eye of the corresponding side, which, however, he considers a doubtful sequela because of the presence of papillitis in the opposite eye prior to the operation; in the second case, he saw sudden and transient mania. Personally, we have seen transient dementia follow mastoidectomy, in which no operative procedure was undertaken on the blood-vessels, and are inclined to ascribe it to causes other than sudden circulatory disturbances. (*Held* (55), *Grossman* (56).)

After-treatment: The after-treatment demands absolute rest in bed. Changes of dressings are to be made with the patient in the recumbent position in bed. A light diet, with rest in bed, ought to be maintained for from ten to fourteen days after the subsidence of all febrile symptoms. The first dressings of the neck-wound in cases which are doing well is made after two or three days, but is indicated earlier if the fever persists. If profuse bleeding has occurred at the torcular end of the opened sinus, this plug is not to be removed early. As stated above, this plug may be rapidly changed at the end of eight to ten days and replaced as long as hemorrhage follows its attempted removal.

If metastatic abscesses are located and are operable, they

should receive prompt surgical treatment, with evacuation of their contents and repeated dressings.

The treatment of pyæmia consists in a sustaining, easily digested diet of milk and eggs, concentrated predigested foods, iron internally, while stimulants are administered as necessary. Collapse is combated by rectal saline injections, and eventually by saline injections by the intravenous route. Small, repeated doses of quinine act well in these cases. Irregularities of the pulse demand digitalis. In other words, active therapeutical treatment is often necessary to rescue a doubtful case, especially where the sepsis is marked before surgical intervention has been possible.

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CHAPTER X

THE SURGERY OF THE MENINGES

Anatomy of the Meninges—Classification of Otitic Meningeal Involvement—Surgery of Extradural Abscess and Purulent Inflammation of the Exterior of the Dura—(Historical)—Surgical Signs of Extradural Abscess—Indications for Operation—Operation—After-treatment—Surgery of the Intradural Abscess—(Historical)—Operation—Dangers—Brain Hernias—Surgery of Otitic Purulent Leptomeningitis—Results of Operations—Surgery of General Meningo-encephalitis.

Anatomy of the Meninges: The brain and the spinal cord are covered by three membranes—an external fibrous one, the dura mater; an internal membrane, the pia mater; and the arachnoid, which lies over the pia mater. The dura mater lines the interior of the skull and forms a loose sheath in the spinal column, enveloping the cord. The pia mater is of loose, areolar, vascular tissue. It closely invests the brain and cord. The arachnoid, the intermediate membrane, is nonvascular in nature, closely connected with the pia at some places, while at others it is separated so far from it as to leave a space of considerable size.

The Dura: The dura mater forms a tissue layer of considerable thickness. It is composed of fibrous and elastic tissue, traversed by blood-vessels, which run principally upon its outer layer. The dura receives filaments from the fourth, fifth and twelfth cranial nerves. Its lymphatic supply is very abundant. The subdural space is in communication with the dural veins.

The dura mater is adherent to the inner surface of the cranial bones; it represents their internal periosteal covering. The connection between the bone and its dural covering is dependent upon numerous blood-vessels and fibrous processes which pass from one to the other of these structures. Except along the lines of sutures, where it is closely adherent, the dura is loosely

attached to the bone, especially over the vortex. At the base of the skull, which is irregular and presents many foramina, we find the dura either continued on through the foramina to the external skull surface, finally becoming continuous with the pericranium, or its fibrous tissue is lost in nerve sheaths. Cranial sinuses are formed by the separation of the fibrous layers of the dura.

Toward the brain, and in the interstices between its component parts, there are presented reduplications of the dura, which are respectively designated the falx cerebri, the tentorium cerebelli, and the falx cerebelli.

The Arachnoid: This membrane, situated between the dura and the pia mater, is a thin delicate membrane formed of interlacing fibrous tissue. It contains a few blood-vessels and, while generally not supposed to contain nerve filaments, *Volkman*, *Bochdalek* and *Luscka* (1), have traced parts of the facial and the spinal accessory nerve to this structure. In the cerebral portion it passes from one convolution to another. It bridges the sulci, and is found at places closely applied to the pia mater, especially at the top and sides of the brain. Where it is not adherent to the pia, it forms a space between itself and that membrane—the subarachnoid space, in which the greater part of the cerebrospinal fluid is contained. This space also contains the larger part of the blood-vessels which go to the brain.

The Subarachnoidal Space: This space is rather unevenly distributed over the brain surface. At places it is scarcely demonstrable (over the convexity), while in other brain sections (posterior two-thirds of the base), it presents itself as a wide interval separating the pia from the arachnoid. The widest part of this space extends over the medulla, pons and interpeduncular recess, as far as the optic nerve. A considerable interval is noted posteriorly between the cerebellum and the medulla oblongata, and a widening is furthermore evident above the corpus callosum. Here the arachnoid is stretched across below the falx cerebri.

At the foramen Magendie, the subarachnoidal space is in communication with the ventricles of the brain. Though there is no direct communicating channel between the subdural and the subarachnoidal spaces, yet fluid can pass through the meshes of the arachnoid into the subdural space (*Macewen*, 2).

The Pia Mater: This is a delicate, highly vascular fibrous tissue, closely investing both brain and spinal cord. It entirely covers the cortical surface of the brain, dipping into and lining the sulci. It becomes invaginated at the lateral and third ventricles, forming the tela choroidea superior and the choroid plexus, and at the fourth ventricle, it forms the tela choroidea inferior and the choroid plexus of the fourth ventricle. The pia contains a large number of blood-vessels.

We will discuss the anatomy of the cerebro-spinal fluid in the chapter on lumbar puncture.

Classification of Meningeal Involvement of Otitic Origin: According to *Körner* (3), we classify otitic meningeal invasions into five types, viz.:

1. Purulent inflammation of the external surface of the dura, with or without the formation of extradural abscess—pachymeningitis externa.
2. Internal pachymeningitis, or intrameningeal abscesses.
3. Otitic purulent leptomeningitis.
4. General meningitis, or meningo-encephalitis; and,
5. Tubercular otitic meningitis.

1. **The Purulent Inflammation of the External Surface of the Dura,** and the formation of extradural abscesses, is the most frequent otitic intracranial complication. It happens at all ages, occurs more often on the right side than on the left side, and is generally the sequela of an extension of bone necrosis, caries or cholesteatomatous degeneration of the temporal bone. *Jansen* (4) finds it more often the complication of an acute than of a chronic middle ear suppuration.

The bone disease usually has extended to the dura; occasionally, a fistulous suppurating tract leads to the dura. An accumulation of purulent exudate most frequently affects the cerebellar region. Often the extradural pus collects in the form of a perisinal abscess.

When the abscess affects the middle cranial fossa, it is located over the tegmen antri and tympani. A rarer situation, but one to bear in mind, is a pus accumulation over the tip of the temporal pyramid. The bone is usually not broken down when the abscess complicates a chronic middle ear suppuration. The bone,

however, is then found discolored, interlaced with fistulous tracts, and often presents sequestra formations in some locality.

The dura is found discolored, and often covered with granulations at the juncture of the diseased bone with the dura. Occasionally, the membrane shows surface ulcerations, infiltrated with purulent exudate. On the other hand, sometimes we only find the dura thickened, lifted off from the bone, with a thick stream of foul-smelling pus coming away from the exposed area.

I consider the difference of these findings one rather of degree than of kind. The findings depend largely upon the time when the lesion is discovered. An earlier operation may discover only a thickened dura, where a later one would have disclosed an ulcerated membrane. The virulence of the invading microorganism also is a factor in this condition.

2. **Intrameningeal Abscess,** or **Internal Pachymeningitis:** Where the purulent process disintegrates the dura and penetrates to the intradural space, and a general infection of the subdural space has not taken place because of the short duration of the invasion, then an intradural or subdural abscess is formed. Clinically, we distinguish two types (*Körner*):

(*a*). The subdural abscess, accompanied by ulceration of the brain surface. *Macewen* (2) describes this type as an abscess formation between pia mater and dura, circumscribed by adhesions, and presenting superficial inflammation of the brain, and often showing brain ulcerations. An abscess of this type, if firmly circumscribed, may be latent for some time.

The abscess is generally located in the middle cranial fossa. This type yields to surgical intervention, as the reported cases of *Macewen*, *Jansen* (5), *Lucae* (6), and others show. We have come across this type of cases, some showing multiple brain ulcerations, and have seen full recovery take place after evacuation of the pus. Occasionally, the abscess locates in the cerebellar region, a case having been reported some time ago by *Heine* (7). In his case, which recovered after operation, the causative disease was a chronic middle ear suppuration.

This type of intradural abscess is almost never recognized before operation. When relieved surgically, recovery is usually prompt.

(*b*). The second type of intrameningeal abscess occurs with a diffuse involvement of the subdural space. This type of case is usually observed in connection with extradural abscesses, sinus thromboses and actual brain abscesses (*Körner*). The lesion presents a variety of characteristics, because of its extent and varying complications. Diagnosis is rarely possible, except upon the operating table. Response to surgical measures is generally prompt and recovery usually takes place, as the cases reported show (8).

Finally, there are cases which cannot correctly be classified as either extra or intradural. These present features of both classes and, often in addition, have rather deep ulcerations, or necrotic areas on the brain surface proper.

A case which I saw with Dr. *R. Johnson Held*, and which has as yet been unpublished, gave the following operative findings:

Upon removal of the mastoid cortex, considerable pus, granulations and bone detritus were uncovered. The entire cellular character of the mastoid had been destroyed under the purulent attack. The inner tablet of the mastoid was entirely absent, exposing the sinus and the cerebellar dura, which was covered with discolored granulations. The tegmen over the aditus and the antrum was absent. The necrotic inflammatory process had destroyed the entire external (lateral) aditus wall and the greater part of the posterior tympanic and external auditory meatal wall. In other words, nature had attempted to perform the radical mastoid operation.

Examination, after cleaning out the mastoid cavity, revealed the absence of the osseous tympanic floor, the dome of the jugular bulb being exposed to the contents of the suppurating tympanic cavity. The facial nerve was found exposed, diseased and imbedded in granulations (paralysis was present before operation). The bony framework of the Eustachian tube had disappeared under the purulent attack, as well as the anterior tympanic wall, exposing the capsule of the joint of the lower jaw at the glenoid fossa.

The dura over the aditus and tympanic cavity was perforated, pus exuding from the opening. Upon exposure of the brain

surface, a sloughing ulcer was uncovered, 1½ cm. in area, with a depth of ½ cm.

The case made a complete recovery under appropriate treatment, but died one year later of an intercurrent disease. An autopsy was not obtained.

3. **Otitic Purulent Leptomeningitis:** This lesion occurs as an involvement of the pia mater, and may present itself either independently of, but as a coincidence to sinus thrombosis or brain abscess, or it may be the result of any of these lesions. In its uncomplicated form, in comparison to brain abscess or sinus thrombosis, it is a rather rare sequela of middle ear suppuration.

Otitic purulent leptomeningitis, although prevalent at all ages, is nevertheless, rather rare in infancy and early childhood, according to *Heine* (9), *Körner* (3), and *Henoch* (10). The pia is generally found diffusely infiltrated. The pus seems to travel along the blood-vessels of the pia and dips into the brain sulci with their pia covering.

Ulcerations of the brain surface may be seen. Often rather small surface abscesses are formed (*Martin*, (11), *Burkner* (12), *Bezold* (13), *Wolf* (14), and *Körner* (15)). These findings are usually seen when the case is of long-standing duration.

Sometimes the pus enters the ventricles, as personal observation demonstrated (case cited in full below).

The greatest pus accumulation generally occurs where the meningeal disease is caused by contact with the affected bone, and the location of the abscess formation is sought for at the demonstrable point of contact (19). The meningeal involvement spreads from this point. In rare cases, the point of contact of dura and diseased bone does not locate the greatest pus accumulation; on the contrary, this is found distant from the region of primal infection, i.e., for example at the Sylvian fissure. Sometimes no macroscopic evidence of disease is presented by the pia mater (*Ray* (16), *Panse* (17), *Knapp* (18), etc.).

According to the origin of the infection, we find the pus spreading along at the base of the brain overlying the tegmen, on the diseased side, and along the inner table of the mastoid process. It gradually reaches toward the vertex of the brain, traveling along the brain convexity, and finally, involves the base of the opposite

hemisphere and the cerebellum. Death generally supervenes before the pus can spread far along the base toward the opposite side (*Körner*).

When the intrameningeal purulency is the result of a labyrinthine infection, we usually find that the meningitis originates in the cerebellar region. Autopsies show the affected side to give pus localized over the cerebellum, with a tendency to spread toward the opposite side of the head. The pus often spreads down along the spinal cord, involving the base of the cerebellum in its advance.

The discussion of the diagnosis of purulent leptomeningitis is not within the scope of this work. Suffice it to say that the rapid development of the lesion, the demonstrable origin of the infection, tend to make the diagnosis easy.

Severe mental disturbances, with both clonic and tonic spasms involving the muscles of the extremities, or with the advent of a one-sided paralysis are significant data. Symptoms referable to the cord add to the certainty of the diagnosis. Opisthotonos, myosis, etc., if present, are characteristic, although the disease may be present without such signs. Extradural abscesses of cerebellar origin occasionally show opisthotonos. The *Kernig* sign speaks for meningitis, although it is also observed in other diseases. *Körner* missed it in extensive involvement of the meninges.

The differential diagnosis between otitic purulent meningitis and a meningitis coincidental to otitic disease is extremely difficult.

We refer the reader to the chapter on lumbar puncture, for data which may aid in differentiating between the various intracranial complications.

4. **General Meningitis or Meningo-encephalitis:** This form of intracranial lesion has as yet not been established upon a satisfactory scientific basis. *Levi* (20) endeavors to show its similarity to the serous effusion observed in the pleura, where caries of the ribs is present, or to the serous effusion at the epiphysis of long bones when these are the seat of osteomyelitis.

The pathological data are exceedingly meager. The records and personal observations show many cases of meningo-encepha-

litis following middle ear suppuration which have completely recovered. *Körner* remarks that these cases were diagnosed from their clinical findings only. The material at hand does not permit of a classification of these cases according to their pathological aspect. Finally, the nature of the process with which we are dealing is as yet obscure. We must still determine whether the symptoms presented arise from a single pathological process, or from a great variety of conditions. The varying clinical picture is the chief disturbing factor in solving this question.

The following characteristics are fairly constant. The disease —meningo-encephalitis—attacks the young with greatest frequency. The signs of meningo-encephalitis serosa often supervene after the mastoid surgery on a previously uncomplicated middle ear, labyrinth or mastoid purulency (*Hertzog* (21), *Jansen*, *Hegener* (22), and *Körner*). In addition, opacity of the optic discs is noted in many of the severe, and quite a few of the less severe cases. Such opacity is absent in otitic lepto-meningitis.

5. Otitic Tubercular Meningitis: Caries of the temporal bone is often seen in connection with tubercle of the brain. *Henoch* (23) finds that tuberculous meningitis occurs most frequently in combination with caries of the temporal bone. Among children it is relatively observed more often than either purulent meningitis or brain abscess. The cranial cavity is usually invaded by the blood-vessel route. Occasionally the disease reaches the meninges from the middle ear spaces through infection by contiguity (24). A rather rare mode of invasion is reported by *Macewen* who, reporting Case XXI, found the meninges to have been invaded through the petrosquamosal suture.

The Surgery of Extradural Abscess and Purulent Inflammation of the Exterior of the Dura: Historical: A case of extradural abscess upon which an operation had resulted successfully, reported by *Schondorff* (25), drew attention to the conditions designated as pachymeningitis externa, and extradural abscess. *Körner* reports that these conditions had been observed as early as 1822 by *Abercrombie* and *Itard;* by *Toynbee*, 1851, *Lebert*, 1856, *Huguenin*, 1876, and *Heinicke*, 1882.

A very full and complete description of these lesions appeared from the pen of *E. Hoffman* (26), in 1888. He traced

the mechanics of the meningeal lesion from the temporal bone through the blood vessels of the arachnoid membrane.

Since then, both at home and abroad, numerous cases have been reported. The discovery of extradural abscesses is to-day an experience common to all otological surgeons.

The Surgical Signs of Extradural Abscess: As a general rule, the presence of extradural abscess gives few objective signs indicative of its presence. A very copious flow of pus, by which large quantities of purulent matter are discharged at the external auditory meatus, leads to a suspicion that such a flow must originate from a collection of pus greater than the middle ear spaces could accommodate and, hence, such a finding suggests an intracranial abscess which is emptying through the ear. *Toti* (27) cites a case in point.

The presumption that an abscess of the character under discussion exists is intensified when the excessive purulent otorrhœa is of short duration, and then recurs, and simultaneously with the advent and cessation of the otorrhœa, symptoms of cranial irritation appear and disappear, only to again become evident just before the profuse discharge again commences.

Subcutaneous infiltration behind the mastoid process in the region of the mastoid emissary vein, if accompanied by a purulent otorrhœa, gives presumptive evidence of the existence of an extradural abscess in the posterior cranial fossa. This may or may not accompany a phlebitis of the sinus transversus (*Jansen*).

Generally, the extradural abscess is uncovered only at the time of the mastoid exenteration. Then the removal of diseased bone leads the surgeon to the affected dura and to the final disclosure of the abscess formation.

Indications for Operation: Surgical intervention is indicated as soon as pus is suspected between dura and bone. *Lane* (28) suggests that the regional opening from the middle ear into the posterior cranial fossa be made so as to uncover the dura in every case, wherein actual pus or cholesteatoma is found when operating on the mastoid. In substantiation for this apparent radicalism, he cites cases in which extradural collections of pus were thus uncovered, of whose existence he would otherwise have been unaware. *Körner*, following this idea, also

ncovered undiagnosed and unsuspected abscesses, and personlly, I have emptied unsuspected abscess formations because of n accidental opening made through the tegmen during masoidectomy.

The uncovering of a small dural area over the tegmen, or over he sinus wall, to demonstrate the absence of a purulent collecion underneath the bone is in itself a perfectly harmless proedure, and I am sure, were the procedure advocated by *Lane* to e universally adopted, many a circumscribed pachymeningitis xterna would be evacuated long before symptoms of its presence ame on. When symptoms supervene, in such cases, it is genrally because the pus collection has broken the circumscribing arriers at some point and is tending to become a diffuse meninjeal inflammation.

The Operation: When a fistulous tract points the way to the lura, a small artificial opening is made in the bone over the dura luring the performance of mastoidectomy. This is to determine the presence or absence of extra dural purulency. The naneuver is easily performed through the skillful use of a small urette, breaking through the tegmen or inner table at the susoected spot. Where no pus is uncovered, the operation on the nastoid is completed as if no dural exposure had been made.

The exposed spot is covered with a small plug of iodoform gauze, and dressings and after-treatment carried out as usual.

Fistulous tracts leading to the dura occasionally are apparent at changes of dressings, having been overlooked at the ime of operation. When thus discovered, their extent should oe explored, and they demand thorough eradication. If they ead toward the dura, a search for extradural pus is indicated.

In cases where the bone surgery has left quite an area of dura ncovered, there often will be found evidences of a flow of pus rom between dura and the bone edge. The area exposed should oe enlarged immediately. A small-beaked rongeur, or the spoon urette, is introduced between the dura and the bone, and the one chips carefully removed, until the opening is widened. When removing the inner table, the dura itself must not suffer injury by the instrument or by jagged bone splinters. Splinters, if left *in situ*, act as local irritants and add additional inflam-

matory factors. Where an extradural abscess of great extent is uncovered, whether located in the middle or the posterior cranial fossa, the bone removal, to give full exposure, must necessarily be extensive. I have repeatedly exposed the dura overlying the tegmen from the cortex externally (laterally) to the region over the semicircular canal, and have never observed an ill effect to follow, provided all the accumulated pus and all the necrotic bone were eviscerated.

When the purulent collection is evacuated, and the mastoidectomy completed, the wound cavity is thoroughly washed with a solution of hydrogen peroxide, followed by one of hot bichloride of mercury (1:2000). There seems a hesitancy on the part of some to use the mercury solution in the presence of exposed dura. Speaking from personal experience, I never saw any ill effects from its employment and, on the contrary, have often seen questionable-looking granulations of dirty greenish color, clean up in a few days after evisceration of the causative factors in the mastoid, followed by the bichloride wash. The cavity is wiped dry; the exposed dura gently covered with iodoform gauze and a second strip used to pack the mastoid cavity. The external dressings follow.

The After-treatment: The after-treatment is along the line indicated in the chapter on the simple mastoid operation. Dependent upon the condition of the exposed dura, subsequent procedures are so far modified that the frequency of dressings is changed. These occur much more often, as a general rule. When the evacuation of pus is accomplished and the dura is found intact, the membrane itself should not be interfered with. When the dura is found covered with granulations which are of dirty appearance, or where it looks suspiciously like breaking down, or sloughing, we gently wash the affected parts with a weak bichloride of mercury solution, and then apply the dressings. Granulations are not to be removed, nor should the dura be scraped. The dressings are changed frequently; often this occurs daily. The granulations are thus daily inspected and treated to an antiseptic bath, until they begin to look clean, after which the treatment proceeds as in uncomplicated cases.

Even where signs of ulceration on the dural surface are evident,

the procedure is not varied, except perhaps to exercise a closer supervision over the case, and to watch the behavior of the exposed and diseased dura.

If the extradural abscess was uncovered during the performance of a radical mastoid operation, the cutting of the plastic skin flaps is postponed until late in the post-operative period. Flaps should never be placed upon exposed dura which is covered with sickly granulations, because when flaps are so placed they will not become adherent. They usually break down, and as they suppurate, may lead to an ulceration of the dura.

If the pus collects over the angle of the temporal pyramid, and is deeply situated, some difficulty may be encountered in evacuating it. Such cases fortunately are rare. For their relief, *Jansen* (29) advocates opening into the labyrinth in addition to opening the abscess from its accessible portion alongside of the petrosal pyramid. General surgical principles should prevail in managing these cases. Finally, cases of extradural abscess, in general, demand careful supervision to recognize the first symptoms of a general invasion of the meninges.

Surgery of the Intradural Abscess: Historical: The first recorded case of intradural abscess is that published by *Cecci*, and cited by *Bergmann*. Other cases have since been recorded by *Macewen*, *Leizinski*, *Milburg*, *Lehr*, and others (8).

The Operation: The mastoid exenteration is first completed. Any pus found between the dura and the bone is fully evacuated. The dura is exposed, by the removal either of the tegmen or of the inner table, as the case may demand, making access to the seat of the intradural lesion easy. Wherever possible, the dura is exposed until healthy tissue is reached. Occasionally, it is found that the dural involvement is so extensive that this is impracticable.

Often the exposed dura shows discoloration, and usually is blanketed by dirty granulations. Necrotic areas are sometimes observed, with here and there perforations of various sizes, through which pus oozes.

The wound cavity is now thoroughly flushed with hot bichloride of mercury solution, and dried with sterile gauze.

The dura is grasped by mouse-toothed forceps and incised to the desired extent, evacuating the intradural pus accumulation.

When the gangrenous areas of the dura are not extensive, we do not excise the affected zone, but leave it in the hope that the simple incision, with resultant relief of tension, together with antiseptic treatment will perhaps, ultimately save the diseased area. When the gangrenous area is found to be large, we excise it completely, cutting it away with the curved scissors.

The intradural cavity left after evacuation of its contents is carefully washed with hot bichloride of mercury solution, and lightly packed with gauze.

During these procedures, the entire operative field is repeatedly flushed with hot saline solution to lessen the effects of shock.

In two cases under my observation, small ulcerations of the brain cortex were present after removal of the abscess contents. The surface of these ulcerations was carefully wiped with moist, hot sponges; some of the disintegrated cortical tissue was thus removed. Recovery followed light packing with diluted iodoform gauze.

In these cases, after evacuation of intradural pus, subsequent dressing changes should not be too frequent. The parts should be kept at rest. Repeated manipulation of the brain surface causes more or less shock, besides disturbing the process of repair. Unless symptoms of cerebral irritation, fever, or fetid discharge urgently indicate a change, dressings are not changed for from three to five days.

Once firm, clean granulations become evident, subsequent treatment is carried on as usual for the post-operative period. When the radical mastoid operation preceded the evacuation of the intradural abscess, the plastic flaps should not be cut until the successful outcome of the meningeal surgery is manifest.

Dangers: In opening intradural abscesses, the element of danger lies in the possibility of causing a diffusion of the circumscribed abscess. This danger is usually the result of an inordinate use of the hammer and chisel during the bone surgery, or it may happen as the result of indiscriminate wiping the deeper parts with gauze, carried on applicators or long-tongued forceps.

The surgeon must keep this danger in mind, and limit his manipulations to the evacuation of the circumscribed area, and endeavor not to break down any protective adhesions which may have formed.

If the case presents a general intradural invasion, then the removal of the entire tegmen and as much of the inner table of the mastoid as necessary is indicated, to procure free drainage. We have found it advantageous to remove the entire table from the medial side of the sigmoid sinus to the external surface of the bony labyrinthine channels, and then place multiple incisions into the exposed dura to evacuate pus, and effect intradural drainage.

The curette should never be used to remove ulcerated brain cortex. The dry wiping with sterilized gauze usually suffices to cleanse the surface of the ulcerations. Experience has shown that the brain surface is easily broken down, and unpleasant sequelæ ensue if the curette is used.

Brain Hernias: Brain hernias are often seen as an after result of intradural surgery. The brain substance protrudes through the incised dura, and sometimes bulges into the external wound. While this is not always avoidable, an attempt to control the condition should be instituted as soon as the brain substance is seen to protrude through the lips of the incised dura.

A suitable pad of iodoform gauze is placed over the prolapsed section of the brain and pressure is gradually exerted by daily tightening the bandage, until the protruding area of brain is replaced. The pads are kept in position until firm granulations hold the relaxed tissues in place.

In a case reported by *Held* and myself, cited below, and two other cases, this maneuver was happily very successful.

Surgery of Otitic Purulent Leptomeningitis: The surgical intervention in cases of otitic purulent leptomeningitis depends, to a certain extent, upon the site of the major portion of the purulent collection.

The objects to be accomplished by the operation on the meninges are as follows:

1. The removal of all diseased tissue in the middle ear and its adnexa.

2. The removal of extra and intradural pus collections.
3. The removal of pus in the accessible ventricles.
4. The relief of intracranial pressure.

The cases on record successfully treated by surgical interference, are as yet too small in number to warrant the basis of a general technique.

The first essential to recovery lies in the complete evisceration of all diseased bone, and all pus accumulations, whether extra or intradural. Following this, and incision into the dura, there is often seen complete cessation of all meningeal symptoms, and final recovery. Cases have been reported by *Macewen* (30), *Gradenigo* (31), *Bertelsmann* (32), *Brieger*, *Wolf*, *Ruprecht*, *Manasse* (33).

As far as I could ascertain, none of the reported cases gives positive evidence of a marked diffusion of the purulent meningitis, with the possible exception of *Macewen's* case (30). The following case, observed with Dr. *R. Johnson Held* (19) gave evidence not only of a diffuse involvement, but the pus was demonstrated in the lateral ventricle and the spinal cord. I cite the case in full:

R. R., female, aged three years, appeared at the Manhattan Eye, Ear and Throat Hospital on December 13, 1904. Her family history was negative.

She never had any of the diseases of childhood and always enjoyed good health until December, 1903, when, following an attack of acute coryza, the right ear began to suppurate; six months later otorrhœa appeared in the left ear. Since that time, until her appearance at the hospital, both ears continued to discharge, and because of this, and the foul odor of the discharge, the patient was brought to the hospital for treatment.

The examination of the right ear evidenced the external auditory canal to be excoriated, presenting a foul-smelling discharge. When this was cleaned away, a thickened, swollen drum, with a large perforation in its antero-inferior quadrant was apparent. The end of the hammer handle had disappeared through necrosis. Examination of the attic gave evidence of extensive necrosis and the presence of granulation tissue. The left ear, upon examination, was found to be in the same condition as the right, but

the involvement was apparently of a lesser degree. A large perforation was situated in the postero-inferior quadrant, but the ossicles were intact. Necrosis was demonstrable in the attic, and considerable inflammatory granulation tissue was in evidence.

Bacteriologically, a smear made from the ear discharges showed a mixed infection with staphylococci and streptococci predominating. The rhino-pharyngeal space was normal.

The patient was put under the usual routine treatment, and kept under observation. No apparent improvement setting in after four months, operative procedures were instituted. On April 29, 1905, the usual radical mastoid operation was performed upon the right side.

Considerable necrosis of the walls of the aditus and of the tegmen antri, besides the usual amount of cell detritus and granulations, was found. Removing the necrotic tegmen antri, an area of dura, about one centimeter in diameter, was uncovered. The exposed dura showed healthy and was left undisturbed. *No pus was found* between the dura and the bone.

Because of the exposure of the dura, no flap was made at this time. The post-auricular wound, being kept open, was lightly packed and external dressings applied.

Bacterial examination of some of the wound scrapings showed a mixed infection of staphylococci and streptococci.

Excepting a reactionary temperature of 101 3-5° F. immediately after the operation, the recovery proceeded without noteworthy incident. On May 9th the plastic flap was cut and the retroauricular wound sutured. On May 19th the bandage was removed, and on May 25th the patient was discharged from the hospital. Nine weeks later the patient's right ear was pronounced cured, dermatization was completed, and the ear found to be absolutely dry.

Meanwhile, both during the patient's sojourn in the hospital and during the post-operative period, the left ear had received careful attention, and had seemingly yielded to treatment, so that when the child left for the country only a slight discharge from this ear was evident. Instructions were given to continue treatment until further report.

No chance was afforded us to see the child again until four months later, when examination revealed the right ear healed, but the left ear (which had probably been neglected) was suppurating, and evidenced an advance in the amount of necrosis.

Here, too, the radical operation was suggested and agreed upon by the parents of the patient, but unfortunately was necessarily postponed because of an attack of scarlatina, and it was not until March 13, 1906, that the radical operation was performed on this side. At this operation the usual findings were made. The antrum and the mastoid cells were filled with detritus and granulations, the attic wall was necrotic, and the tegmen over the entire antrum and aditus, extending to the epitympanic space, was absent, disintegrated by the necrotic process.

The exposed dura, in area 1½ by ¾ cm. was covered with small granulations, and looked darker than normal. *No pus* was found in this region, and nothing indicated interference with the dura. The post-auricular wound was left open, cleansed and lightly packed.

An atresia of the external auditory canal was apprehended, and so it was split, and the edges of the canal flaps tamponed back. Scrapings from the mastoid gave a mixed infection, staphylococci predominating with some streptococci present.

For a week following the operation nothing out of the ordinary was noticeable. The first dressing was undertaken on the sixth day; the wound was found healthy and clean. At subsequent changes of dressings nothing was noteworthy except that the healing granulations appeared rather slowly. On April 8th the child was sufficiently improved to leave the hospital, and for two weeks thereafter appeared daily for dressings. Recovery proceeded slowly, but steadily. Occasionally some discharge from the *middle* ear spaces was evident at the change of dressings.

On May 8th, when the child appeared at the clinic, the mother reported that she had passed a restless night, and that the child had been unaccountably restless and irritable. The dressing showed nothing unusual in the wound. The following night the child cried considerably and was very restless, and vomited. The mother reported that the child was feverish. For forty-

eight hours longer the child was left in the mother's charge, but as the symptoms became more marked, and as a slight retraction of the head became noticeable, for the better supervision of the case, the child was re-admitted to the hospital on May 11, 1906.

Status on Admission: The head was markedly retracted. The pupils were dilated, and the right eye deviated slightly outward. The patient was restless and cried considerably. The temperature was 102.4° F., pulse 144, respiration 75. Immediately upon admission the dressings were removed and careful local examination instituted. Considerable pus was found in the wound cavity and dressings. The wound itself was covered with fairly healthy granulations. The dura was blanketed with thickly sprouting granulations of a dark color, which bulged into the wound cavity. Pulsations of the dura were absent. As an aid in diagnosis, lumbar puncture was made, the blood examined, and the condition of the eye fundus inquired into.

The examination of the spinal fluid by the hospital pathologist showed it to flow with but slight increase of pressure, and to contain principally pus, and a large quantity of extra cellular diplococci which, however, decolorized by *Gram's* method, although they appeared like pneumococci (Report by *Zabriskie*).

The blood examination revealed:

Hæmoglobin	56%
Erythrocytes	5,693,963
Leucocytes	22,648

Differential count:

Large mononuclear lymphocytes	4.0%
Small " "	9.6%
Polynuclear neutrophiles	84.2%
Mononuclear leucocytes	1.8%
Transitional forms	0.4%

The fundus of the eye evidenced unmistakable signs of double choked disc, with decided swelling at the margin of the optic papillæ.

The results of these examinations, taken in connection with the clinical picture which had meanwhile developed—the head

retraction more marked, the divergence of the eyes very evident, the stupor and the somnolence, with fever—led us to a diagnosis of purulent otitic meningitis.

During the next twenty-four hours the clinical picture fully developed. The temperature remained high, ranging from 102° to 103° F., and after consultation it was decided to make an exploratory operation and drain the interior of the dura, and, if possible, afford an outlet for the accumulating purulent exudate.

On May 12th the patient was operated upon, having been in a condition of stupor or unconsciousness for twenty-four hours prior to the operation. The old mastoid wound on the left side was first carefully curetted and enlarged, the mastoid cavity cleansed of granulations, and the surface of the darkly discolored and bulging dura cleared of all granulations. This accomplished, the lower portion of the squamosal plate of the temporal bone was removed, making an opening 3 by 3½ cm. Through this opening the dura evidenced dark and congested. Considerable bulging was evident, but no pus was seen between dura and bone.

The dura was then incised by a horizontal incision extending the entire length of its exposure, along the lower and external edge of the bone wound. Immediately upon opening the dura purulent fluid escaped, estimated at from one to two drams in amount. Unfortunately, because of the suddenness of its appearance, none of this fluid was preserved for subsequent examination. The brain substance immediately protruded in the wound, and was found soft and friable. The wound was then flushed with very hot saline solution, and the brain substance, as far as could be reached, was carefully wiped, the brain was lifted upward gently, and wiped underneath, and a strip of plain gauze was introduced between the base of the brain and the dura, downward toward the interior of the skull. The gauze was kept in one long strip, the end of which protruded, and was finally taken up in the outside dressings. The mastoid cavity was also washed, wiped, and dressed, and the external dressings applied.

The only part of the technique to which we wish to call attention was the frequent flushing of the entire operative field with

very hot saline solution, with the intention of keeping the exposed brain tissue continually warm. The next morning the temperature rose to 105°, pulse 170, and respiration 80. Restlessness and sleeplessness persisted, necessitating the administration of opiates.

On May 14th the left ventricle was entered by means of a *Quincke* needle and canula, and about a dram and a half of purulent fluid removed. Lumbar puncture was now undertaken as a therapeutic measure, and about 40 cc. of a grayish-white, turbid fluid was withdrawn. Microscopically this contained, besides numerous red blood cells due to faults of technique, polynuclear leucocytes, a few small round cells, and an occasional epithelial cell. The cells numbered 410,000 to the cubic centimeter in the following proportions:

Polynuclears	91%
Small mononuclears	8%
Endothelial	1%

The fluid contained a few diplococci intracellulares, about three or four in twenty microscopic fields. Cultures, however, gave a mixed infection, the bacteria present being diplococci and staphylococci, the staphylococci overgrowing the diplococci in the last of a set of cultures. The first of the set and the smear gave a *Gram* negative, and intracellular diplococci present in moderate quantity.

Following the lumbar puncture, a distinct improvement was noticeable. Respiration fell to 24–30 a minute and the pulse to 120–140, and the temperature curve ranged from 101.6°–103.2° F. Sleep was quieter, but restlessness was still marked.

On May 16th another lumbar puncture was made and 30 cc. of grayish fluid withdrawn. Its examination showed a predomination of polynuclear leucocytes, and some endothelial cells present.

The formed elements numbered 330,000 to the cubic millimeter.

Polynuclear leucocytes	73.0%
Mononuclear leucocytes and lymphocytes	25.5%
Endothelial cells	1.5%

There were mostly staphylococci present but some diplococci which were not intracellular. A pure culture of staphylococci was obtained from this fluid.

The patient's condition improved during the next two days, the temperature dropping to between 99.6° and 101.8°, the pulse ranging from 100 to 140, and the respirations from 26 to 30. Restlessness became less marked and sleep more natural. Additional nourishment was now given and retained. Lumbar puncture was again performed on May 18th, and this time 35 cc. of a clear, limpid fluid was withdrawn containing a very small amount of white sediment, some blood, but no coagula.

Lymphocytes now predominated in the cellular content, many polynuclear leucocytes were present, and a few endothelial cells. In number, the formed elements were 295,000 to the cubic centimeter as follows:

Polynuclear leucocytes	45%
Polynuclear lymphocytes	52%
Endothelial cells	3%

A good many amylaceous bodies were found in the fluid and a moderate number of red cells.

A smear made from the sediment showed a very few small cocci, some single and some arranged in pairs, *none were of the intracellular variety*. Cultures made in different media gave a pure growth of staphylococci.

The fundus of the eye still evidenced choked disc, but the swelling of the margin of the optic papilla was less marked.

Decided improvement of the retraction of the head became evident, restlessness was still present, but less marked, and, generally speaking, improvement continued.

The first dressing was undertaken on May 23d, nine days after operation. The gauze drain was removed from the cranial cavity. The wound looked healthy and was covered with clean, healthy granulations. The dura, while thickened, was taking upon itself a lighter color and appeared only slightly congested. At this period, the temperature ranged near the hundred mark, the pulse varied from 106 to 130, and the respiratic between 24 and 30.

From this time on, improvement progressed slowly and gradually. The mind cleared, the temperature gradually came to the normal, nourishment was increased in amount and retained; the rigidity of the spine and the retraction of the head disappeared, the eye fundus cleared—in full, and as far as the meningeal symptoms were concerned the case became entirely well.

Locally, some trouble was experienced in the wound because of a protrusion of brain substance through the dura. This was carefully pushed back by gradually increasing pressure exerted by the external dressing and packing until finally the protruded brain substance was pushed back into the cranial cavity. The mastoid wound meanwhile healed, until to-day it is dry, presenting only a very small post-auricular opening, which at any future time can be closed by proper plastic procedure.

The child was discharged from the hospital on July 8, 1906; phlyctenular keratitis, due to hospital confinement, developed. The child still reports at the clinic for observation. March, 1908.

From this case, and others in the literature (34), it would seem that surgical intervention is indicated in almost all cases. Upon the establishment of a diagnosis of otitic purulent meningitis, the steps to be taken may be enumerated as follows:

1. A thorough exploration of the middle ear spaces to eradicate diseased cells which might have been previously overlooked.

2. Exposure of the dura, by removal of the tegmen or the inner table to locate extradural pus accumulations. The removal of the inner table over the cerebellar region is especially advocated as the most probable region affected.

3. Incision of the dura and drainage of the cerebro-cerebellar arachnoid cavity.

4. Incision of the brain substance in the suspected region to evacuate brain abscesses.

5. Ventricular puncture to evacuate pus in the accessible ventricle (usually later).

6. The repeated use of lumbar puncture to lessen intracranial pressure, and to evacuate cerebrospinal fluid, and to aid regeneration of a new cerebrospinal fluid of heightened bactericidal properties (*Kopetzky*, 35).

In exposure of the dura, the aim should be to make the exposure large enough to afford working room. Conditions present must, of course, govern the procedure undertaken. Suspicious-looking dura, in the presence of meningeal symptoms, should be incised.

When the necrosis of the tegmen antri, the tegmen tympani, or tegmen cellulæ points the way to the route of the intracranial invasion, the dura over these regions should first receive attention; otherwise, in view of the many reports from autopsy material, the dura of the cerebellar region should first be incised.

The incision of the dura in the posterior cranial fossa is usually followed by a considerable flow of discolored, and at times purulent, cerebrospinal fluid.

We have found it convenient and also practical to make a number of parallel incisions, about 3 mm. apart. This tends to accomplish the desired drainage and yet prevent brain hernias. If the lesion in the cerebellar meninges is extensive, it may become necessary to open the skull posterior to the mastoid wound and approach the posterior cranial fossa from behind.

An incision is made in the soft parts, extending backward from the mastoid incision, as far as necessary to uncover the desired area of bone. The periosteum is retracted, and the wound lips turned upward and downward respectively, and held apart by retractors. The bone is taken from the occipital bone, by using either a circular saw, or a small gouge or suitable forceps. The bone is first severed, then lifted, and the dura underneath exposed. Incision of the dura follows:

In some cases a circular flap may be cut from behind the ear, from the skin of the back of the head. To do this the incision is carried down to the bone. At a distance of about a half inch within this incision, the bone is cut through. The entire flap, integument and bone is then turned forward toward the mastoid, hinging upon the uncut part. To facilitate this, the bone itself is split after having been undermined. In other words, we endeavor to make an osteoplastic flap. The thickness of the skull cortex determines the success of this maneuver. The cerebellar dura is thus exposed.

In cases where the tegmen is found eroded, and the principal

lesion is located in the middle cranial fossa, then the entire tegmen is removed. The exposed dura is incised and the pus evacuated.

A flap may be cut from the skin and soft parts above the linea temporalis, as recommended by *Barnhill* (36). Personally, we have used a somewhat similar procedure, but the *Barnhill* method possesses advantages and we give it in full.

A flap is cut, with the concha as its base. This flap is circular and is carried down to the bone, and after separation from the bone is turned down and forward over the pinna. *Barnhill* then opens the skull with a trephine of $\frac{3}{4}$ inch diameter, at a point located $1\frac{1}{4}$ inches above *Reid's* base line, and on a perpendicular raised from the external auditory meatus. The button of bone is removed and kept during the subsequent procedures in a warm sterile normal salt solution. The exposed dura is then examined and, if necessary, incised, and the brain underneath explored. We have found that the trephine opening was not sufficient for our purpose, and instead have enlarged the exposure, removing the squamosal plate until free exposure of the dura followed, leaving *in situ* a ridge of bone roughly representing the continuation backward of the zygomatic root.

The exposed dura is incised in parallel incisions and the underlying brain explored. Usually a free purulent flow follows the opening of the dura, and often brain abscesses are located and thus evacuated. If necessary, the brain is gently lifted and a drain placed through to the tegmentary opening.

If puncture of the lateral ventricle is undertaken, or search for undiscovered pus accumulations is to be tried, these procedures may all be performed from the dural opening thus made.

Gauze drains are now placed in the dural cavity (in the brain cavities itself, if conditions demand it) and the wound of the meninges dressed separately from that of the mastoid cavity.

In all procedures on the brain or the meninges, the dressing of the mastoid wound should be carried on separately from the dressing of the brain and the meningeal wounds. This is true for cerebellar and cerebral lesions, so as to minimize the

possibility of subsequent infection of these regions from the suppurating mastoid wound.

At frequent intervals during the operation on the meninges, the entire operative field should be flushed with hot saline solution. This has been found to lessen systemic shock. The placing of the gauze drains in the dural space requires the exercise of great gentleness, so as not to injure the brain substance.

The first dressing should be so arranged that the gauze from the dural drain may remain undisturbed at the dressing changes of the mastoid. All manipulation of the meningeal areas or of the dural drains adds to the possibility of future infection, to say nothing of systemic shock. At the changes of dressing the gauze in the dural space should not be disturbed. That in the mastoid wound is changed as necessity demands.

As recovery progresses, as the temperature falls and the sensorium clears up, the dural drains are gradually withdrawn until they are entirely removed.

Gauze is now placed over the exposed dura only, and when that period in the after-treatment is reached where the patient is on the road to full recovery, even these are necessary no longer.

Occasionally where a skin flap had been cut, it may be replaced and sutured at once into position after the meningeal surgery is completed. In cases which react promptly to surgical treatment, the flap can be replaced at the end of from ten to fifteen days. Sometimes it can be done at a much earlier period. In certain selected cases, it may be sutured into place at the completion of the exploratory operation, leaving one corner open to permit egress to the drain. The subsequent after-treatment of the mastoid wound is continued as described for the after-treatment of the radical mastoid operation.

Result of Operation: Because of the small number of clinical reports as yet extant, it is almost impossible to formulate statistics on the result of operative interference in otitic purulent leptomeningitis.

I have operated upon six cases with four deaths. Of the cases which died, the principal foci of the intracranial affection were located in the posterior cranial fossa. Furthermore, in

none of the fatal cases could the disease be traced to the meninges by contiguity. Unfortunately autopsies were not obtainable, but it appears to me that the posterior cranial fossa probably became invaded through the labyrinthine channels. Had the disease been recognized and checked in the internal ear some of the cases might, perhaps, have been saved.

In the cases which were cured the disease was shown to have spread by contiguity through the tegmen and inner table to the dura. The labyrinth was uninvolved.

Macewen reports twelve cases of infective purulent leptomeningitis, six of which were operated upon successfully. Of these, five were in the cerebral, and one in the cerebellar fossa.

It would seem, therefore, that tentatively we might say that a meningitis produced by contiguity offered better prospects for recovery after operative interference, than one which followed invasion of the labyrinth, and that the middle cranial fossa when invaded gave a better prognosis as to eventual recovery than obtained from a purulent process in the posterior cranial fossa. In this regard, the advice of *Jansen*, to eradicate labyrinthine purulency as early as possible in order to combat fatal meningitis is called to mind.

The symptoms from the labyrinth are only present in the beginning of the intracranial invasion. Later, in the course of the disease, they are overshadowed by the symptoms presented by the disease of the meninges. Often symptoms referable to the meninges disappear completely after opening in the labyrinth (*Körner*).

At the present state of our knowledge, we hold that otitic leptomeningitis is curable by operative intervention, especially when the route of intracranial invasion is through the tegmen, or the inner table of the mastoid by contiguity. That where the invasion spreads to the meninges through the labyrinth, it responds to treatment, if the labyrinth is early subjected to surgical exploration.

Finally, even in apparently hopeless cases, surgical intervention is justifiable on the ground that the evacuation of accumulated pus from the intradural spaces and from the ventricle, together with the relief of tension offered by lumbar puncture,

may result in the recovery of a case which otherwise would have died.

Surgery of General Meningo-encephalitis: In many of the published cases of general meningo-encephalitis, lumbar puncture, either alone or in connection with exploratory puncture of the meninges over the region which produced the most marked symptoms, has resulted in full recovery. In many of the cases reported as having been cured, *Körner* notes that no pus was found. A rather free flow of clear fluid was obtained from the meshes of the pia mater or from the lateral ventricle. In certain of the cases, not even cerebrospinal fluid was obtainable. Recoveries occurred with all these varieties of findings. These cases created the impression on *Körner*, as if they were cured through the eradication of the primary lesion in the temporal bone.

The disease is appreciated only from its clinical picture. Positive diagnosis is almost impossible. The disease is studied from its course, its operative findings and the results from operative exploration of the meninges. Symptoms of headache, vomiting, fever, opisthotonos, etc., may as often mean disease of the brain substance as an affection of the meninges. *Heine* believes that the findings at operation deliver the only data to the actual conditions present in the given case. The operative procedures to eliminate the causative disease—the purulent mastoid and middle ear, including the labyrinth, if it is diseased—with free exposure of the affected brain area, often result in the cure of the condition.

Spontaneous cures, in cases where severe cerebral symptoms followed the operation on the mastoid, are by no means uncommon, and, therefore, *Heine* advocates expectant treatment for a short time in these cases, to await the clinical developments. Incision of the dura—either single or multiple, to relieve pressure by evacuating the accumulating cerebrospinal fluid, together with repeated lumbar puncture, and if indicated—ventricular puncture, are the measures which eventually find useful employment in combating the disease.

Tubercular meningitis of otitic origin does not seem to yield to surgical treatment. The invasion of the meninges is usually

dly followed by a mixed infection which generally ends lly.

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CHAPTER XI

SURGERY OF OTITIC CEREBRAL, AND OTITIC CEREBELLAR ABSCESS

Historical—General Consideration of Otitic Brain Abscesses, (Eburnization, Characteristics of the Causal Lesion in the Temporal Bone, Surgical Trauma, Causative Factors, Site, The Abscess, Destiny of the Abscess, Stages of Development) —Diagnosis of Otitic Brain Abscess—Some Differential Diagnostic Points Between Cerebral and Cerebellar Abscess; Between Cerebellar Abscess and Purulent Labyrinthitis, Differentiation Based on Nystagmus; Differentiation from Meningitis; Differentiation from Other Nervous Diseases and General Conditions—Indications for Operation—Operations for Abscess Located in the Middle Cranial Fossa—Operation for Cerebellar Abscess—Treatment of the Abscess Cavity—After-treatment—Immediate Effects of Evacuation—Results of Operation—After Effects of Otitic Brain Abscess.

Historical: *Hippocrates* (1) recognized the coincidental occurrence of ear disease and brain abscess; at a much later period *Morgagni* apparently realized that ear disease stood in casual relationship to the brain abscess. In 1856, *Lebert* (2), as the result of independent investigation, fully established the etiological rôle played by the ear suppuration in the production of brain abscess.

The first recorded recovery after surgical intervention in a case of brain abscess was published by *Morand* (3), in 1768.

The second case successfully subjected to operation is recorded eighty years later by *Roux* (4); in 1881, *Macewen* (6), in 1886, *Schede* (5), and then *Hulke* (7), published the results of their operations on cases of brain abscess. The middle of the eighteenth century saw the introduction of the surgical treatment of brain abscess.

Hulke operated upon three cases, and published a series of observations and criticisms of the cases, which really laid the

foundation of otitic brain surgery. Later, there followed reports from *Barker* (8), *Greenfield* (9), *Macewen* (10), *Ferrier* (11), *Horsley* (12), and others.

In Germany and on the Continent generally, an added impetus was given to brain surgery by the excellent work of *v. Bergmann* (13) and *Körner* (14), while in America, *Bacon* (15), *Burnett* (16), *Croly* (17), *Dench* (18), *Gruening* (19), *Knapp* (20), *Myles* (21), *Richards* (22), *McKernon* (23), *Phillips* (24), *Randall* (25), *Lederman* (26), were among the earlier of those who reported cases.

From these reports the groundwork was laid for otitic brain surgery, and the literature is rich* in both native and foreign contributions to this important branch of otological surgery.

General Considerations of Otitic Brain Abscess: *Gowers* finds from the literature (cited by *Oppenheim* (34),) 186 cerebral as against 41 cerebellar abscesses, while *Fort* and *Lehman* find 327 cerebral as compared to 113 cerebellar abscesses. *Körner* (14) adding the autopsy findings of *Pitt* (35), *Treital* (36), *Gruber* (37), and *Poulson* (38), finds there are almost twice as many cerebral as there are cerebellar abscesses.

On the other hand, it seems questionable whether the cerebellar abscess is really as rare as these statistics would suggest. *Okada* (39) recently raised this question, and the reports of *Dench* (40), who studied 102 cerebellar and 100 cerebral abscesses makes one question the correctness of *Körner's* conclusions from findings at autopsy.

Grünert (27) finds that 91% of brain abscesses are complications of the chronic type of middle ear suppuration, and 9% are induced by an acute middle ear suppuration. More recent statistics, although in a general way substantiating these results, lower these figures somewhat for the chronic middle ear disease. Thus *Hammerschlag* (28) finds that 75% of otitic brain abscesses are induced by chronic ear disease, while 25% are the result of acute middle ear suppuration.

Regarding the relative frequency of the occurrence of otitic brain abscesses in middle ear suppuration, *Jansen* (29) finds that

* It is impossible to cite full literature. Those interested are referred to *Körner's* books, especially his latest, "*Nachtrage*"; also *Dench*, "*Transactions American Otological Society*, 1907.

the abscess appears once in 2,650 cases of acute middle ear suppuration, while in the chronic type of the middle ear disease he finds that it occurs once in 2,500 cases. It follows, therefore, that otitic brain abscesses are collections of pus within the brain substance, generally induced by a chronic suppuration within the temporal bone, although they are often the result of an acute process.

In the vast majority of cases, the chronic middle ear suppuration is of long standing, and pathologically it is found to be a disease of the bone, that is—the causative lesion in the middle ear spaces is not a chronic suppurative process limited to the lining mucous membrane of these spaces, but is an actual disintegrating process due to bone necrosis, caries, or the erosive action of cholesteatomatous masses.

Eburnization: Before further discussing otitic brain abscess, I must revert to the rôle played by bone eburnization. This process of eburnization is in a way a regenerative process, and goes on simultaneously with the destruction of bone at other points. Individual sections of the temporal bone become sclerotic and hard, while other portions undergo destruction. Since the destructive necrotic process does not attack the individual sections of the temporal bone with equal relative frequency, and since the process attacks the mastoid process most frequently, and in descending percentages, involves the sigmoid fossa, the tegmen tympani et antri, and finally the petrosal pyramid (*Neuman* (30),), it follows that the individual pneumatic spaces disintegrate in the lines of least resistance. The mastoid cortex being most frequently the seat of eburnization, the line of least resistance is toward the cranium; when, therefore, eburnization is present as a factor of middle ear suppuration, the chances of a brain abscess forming in a chronic bone lesion in the temporal bone are increased appreciably.

The view heretofore held that eburnization interposed a protective barrier of osteosclerotic bone around the vicinity of the necrotic process, to afford protection against an extension of the infection to the brain and men nges, requires revision in the light of more recent investigation. Findings, both at autopsy and at operation, demonstrate that the sclerotic process is

generally absent in situations where its presence might best act as a protective barrier.

Characteristics of the Casual Lesion in the Temporal Bone: *Neuman's* (30) statistics show that the ear suppurations associated with cholesteatoma furnish the largest percentage of cerebellar abscesses; the cholesteatomatous masses produce erosion of the bone by direct pressure. Furthermore, the partial disintegration of the masses, especially at their periphery, adds material which furnishes ready soil for bacterial propagation. The enlargement of the cholesteatoma naturally leads this infection toward the cranial cavity. Experience teaches that cholesteatomatous masses usually involve the antral region, and thus the destruction of sections of the mesial wall of the antrum mastoideum (labyrinthine capsule, semicircular canals or sinus) opens the way for bacterial invasion of the cerebellum.

Whether the original disease in the temporal bone consisted of a simple caries or an active necrotic lesion, characterized by eburnization or not, or whether the lesion happens to be an acute disintegrating process; or whether it was the result of cholesteatomatous growth in the middle ear spaces, the lesion in the temporal bone is usually characterized by extension of the disease to the bone overlying the dura. *Körner* (31) finds that the bone lesion extended to the dura 62 times in 90 cases. In a more recent report, he finds in 40 otitic brain abscesses that the bone was diseased down to the dura 37 times. The bone was diseased in one other case of this series, but not down to the dura. In only two of the 40 cases did healthy bone intervene between the disease in the middle ear spaces and the dura. In about half of the cases where the bone showed involvement down to the dura, this membrane was also found to be more or less diseased.

Where the dura is simultaneously involved, it usually is found adherent to the surface of the brain. A greater or lesser amount of brain substance intervenes between the meningeal lesion and the brain abscess proper. Generally this intervening tissue is a thin layer; *Körner's* statement that the abscess is located in close relationship to the diseased bone is borne out by the findings in such cases.

Occasionally, as is demonstrated at autopsy, the intervening

brain tissue is normal in appearance and apparently covered with healthy dura. From this, it is argued that the pus is not necessarily propagated in one direct, broad, continuous tract, but it may reach the site of the abscess by way of the lymphatic channels, or by way of the pial vessels; the propagation of infectious micro-organisms finally lodging, at a greater or a lesser depth, beneath the brain cortex to create the abscess in the brain substance.

Jansen (31) holds that lateral sinus thrombosis does not seem to stand in causal relation to otitic brain abscess. This observation seems to be substantiated by numerous necroscopic reports, although a small number of cases with thromboses have been reported. A case wherein the thrombosis was evacuated, but the abscess overlooked, recently came under our personal observation (57). The coincidental existence of these lesions must, therefore, be kept in mind, for *Koch* (32) finds that sinus thrombosis and cerebellar abscess are coincidents in at least half of the cases. Dehiscences in the anatomical structure of the temporal bone have little bearing on the production of otitic brain abscesses.

Causative Factors: The causative factors have been partly discussed in speaking of the characteristics of the original bone lesions in the temporal bone. If unrelieved, purulent labyrinthitis is a causative factor of cerebellar abscess.

Surgical Trauma: Finally, otitic brain abscesses may result from trauma to the head. To be more correct, we should say that symptoms of the abscess commence to show themselves after trauma. (*Barr*, (33).) Trauma may be either accidental or surgical. The non-otitic abscess, caused by trauma, belongs to the domain of general surgery. There is much of interest to otologists in the cases caused by surgical trauma.

There are many cases of chronic middle ear suppuration which go on from year to year, exhibiting a purulent otorrhœa. These patients, although apparently healthy, if closely questioned, will give evidence of being indefinitely ill at times, suffering from rather indistinct headache and slight spells of dizziness. Because of the slightness of their symptoms, and the readiness with which other causes are assigned for the existence of their indisposition

—indigestion, poor eyesight, malaria, etc.—the patients fail to recognize these signs as evidences of a complication from their purulent ear disease.

When such cases have lasted many years—one of mine had a purulent ear for twenty-seven years, an abscess being uncovered at operation—and when they finally submit to mastoid operation, in the hope of curing their ear suppuration, the jarring of the head—due to the chiseling which partial or complete eburnization necessitates—may arouse into activity an abscess heretofore quiescent. The mastoid operation undertaken to cure the middle ear suppuration thus stands in direct causal relation to the activity manifested by the abscess, acting in a manner similar to accidental trauma.

No one is in a position to know how soon such an abscess would become manifest, had no operation been undertaken, nor should these cases be used as arguments against the radical mastoid operation, to substantiate the claim—where there are histories as outlined above—that the mortality from the brain abscess is increased by the radical operation. Given a pus collection in the brain more or less continuously fed by a middle ear suppuration, then there will still remain the fact that under ordinary conditions, a sudden jar, slight fall, or a slight blow on the head, to say nothing of more severe injuries, will bring the same factors to bear on the quiescent abscess as the operation would, and the result might be the same, namely, the manifest activity of the abscess.

I believe it to the best interest of the patient to take the chances of waking up a latent abscess, and evacuating it, if its presence is shown by symptoms, rather than to permit the possibilities of active manifestations to deter the surgeon from eradicating the bone disease in the middle ear spaces. I am of this opinion all the more in view of the possibility that any slight trauma may place the patient in jeopardy of his life. Furthermore, when a quiescent abscess becomes active, in the presence of a long standing middle ear purulency, the clinical picture is obscured from the start, and differential diagnosis most difficult.

Site: Otitic brain abscesses are generally found in the imme-

diate neighborbood of the diseased bone; they occur more frequently on the right than on the left side.

When the bone lesion is found to have involved the roof of the external auditory canal, the tegmen antri or the tegmen tympani, in the majority of instances the abscess occurs in the cerebrum—the tempero-sphenoidal lobe. The cerebellum is the seat of the abscess when the original disease is found to have involved the labyrinthine channels, or the inner mastoid table.

Among children, the cerebellum is the seat of the abscess more rarely than among adults.

Otitic brain abscess may be simple or multiple. *Körner* (14) finds them multiple 15% of times.

The Abscess: Brain abscesses vary greatly in size. The size of the abscess does not correspond to the intensity of the symptoms. A large abscess may be present with no symptoms to speak of, or a small one may give many definite signs of its presence. The symptoms depend rather upon the part of the brain involved, than upon the amount of pus collected. The size of the abscess does not necessarily correspond to the amount of apparent intracranial pressure.

The abscess is either encapsulated or it is without definite boundaries. *Hessler* (41) finds that in 49 abscesses induced by chronic otitis media purulenta, 32 were encapsulated, while 17 were not. In 13 abscesses produced by otitis media purulenta acuta, 5 had capsules and 8 were not encapsulated.

The capsule is a pyogenic membrane of varying thickness. It is usually smooth on its internal surface, often showing gentle elevations, and covered with ecchymotic spots. This membrane may be more or less vascular.

According to *Macewen* and others, the encapsulation of an abscess does not prevent its increase in size.

The contents of the abscess cavity generally consists of thick, cheesy, yellowish brown, or greenish pus, which is often fetid. Sometimes the odor is entirely absent. In addition to the pus, the cavity may contain detritus and blood.

The Destiny of the Abscess: Otitic brain abscesses terminate in one of the following ways:

1. They may be absorbed (*Macewen*). This is a rather rare termination, although it is perfectly possible.

2. They may empty spontaneously. The abscess contents may drain off through a fistulous opening in its capsule, or through a pathological opening in the bone and capsule; such cases are reported by *Randall* (42) and *Gribbon* (43), and others, who have observed otitic brain abscesses which drained through such openings, the pus finally coming away through the ear. *Macewen* terms the drainage of such an abscess through the ear, a kind of otorrhœa cerebralis.

3. The abscess may rupture. Rupture takes place into the neighboring ventricle or into the subdural space. When the rupture takes place into the subdural space, a purulent meningitis is started. The rupture of a cerebellar abscess into the subdural space starts a cerebrospinal meningitis into existence. The rupture into the lateral ventricle may result in an encephalitis, or if the rupture takes place into the fourth ventricle, paralysis of respiration and instant death may result.

Although patients have been known to carry an abscess for a long period of time, eventually the presence of such a pus collection within the brain means death if unrelieved. An abscess may recur after a period of apparent cure.

The Stages of Development: Otitic brain abscesses pass through four stages in their development. These stages are differentiated according to the clinical pictures presented during various periods of their growth.

The first stage, designated the initial stage, is generally unrecognized. Clinically, it presents nothing characteristic. It is often obscured by the symptoms of the disease in the ear. In some cases, the initial stage and the manifest stage are merged, but in the larger number of cases the initial stage is followed by the second or latent stage.

When marked, the initial stage exhibits headache and vomiting. The duration of this stage may only be a few days.

The second or latent stage presents symptoms of headache, psychical depression and a slight evening temperature. This stage usually lasts for some time. It may extend for weeks, and has been known to have existed for years. It is often marked

by periods of remission, when all the symptoms are absent and the patient is apparently, for practical purposes, perfectly healthy.

The third stage in the development of the abscess is the manifest stage. During this period, the abscess makes its existence known by an actual clinical picture. This period varies in duration from a few weeks to some years. It seldom, however, exceeds two months in duration. (*Jacobson* and *Blau* (44).)

The last is the terminal stage. This period marks the growth of the abscess, with the advent of symptoms referable to its presence and with the near and distant effects of pressure which it exerts upon the surrounding brain tissue. The terminal stage includes the time up to rupture of the abscess, either externally on the brain cortex, or into the ventricles or into other anatomically neighboring parts. It usually either terminates with the patient's life, by sudden arrest of vital function, or it starts into activity a purulent meningitis, or finally the abscess is evacuated before the patient succumbs.

Trauma, or psychical irritation, a blow or a fall, tend to bring on the terminal stage directly after the latent period. In such cases the disease usually progresses without symptoms almost to the end.

Diagnosis of Otitic Brain Abscess: The symptoms of brain abscess may be divided into the following:

1. Symptoms due to pus retention (general symptoms).
2. Symptoms due to pressure on the brain (brain symptoms).
3. Symptoms due to the site of the abscess (local symptoms).

The most important of the general symptoms is the temperature curve. Occasionally, the disease starts with a chill, or it begins like a meningitis. Repeated chills have been observed, although these, as well as high fever, are to be considered as an exception. It is difficult to determine whether or not in a given case the fever is from the original bone lesion, or from the complicating abscess. As a general rule, uncomplicated abscesses give subnormal temperatures. (*Heine*, (45).)

In the early stage, the patient exhibits malaise, lack of appetite, and if the initial stage continues long, progressive emaciation supervenes. Constipation is the rule and there is generally

a foul odor to the breath. The tongue is markedly coated. Often there is some nausea and vomiting.

These symptoms are so indefinite that they might indicate any complication of the original disease. They possess value only when all other possible sources of pus retention have been eliminated.

The symptoms from the brain are more marked in the cerebellar than in the cerebral cases. The most significant symptom presented is the headache. This is found in varying degrees of intensity. It is present in almost all cases, although occasionally, as shown by *Heiman* (46), it is absent.

At times the headache is characterized as a feeling of heaviness in the head; it may become so intense that it is hardly bearable. The headache is usually more severe during rises of temperature. It is intensified by anything which congests the head, e.g., pressure exerted during stool, bending forward, or lifting heavy weights. Any act or condition of the patient which produces increased blood pressure will increase the intensity of the headache. The headache is sometimes characterized by periods of remission, *Schwartze* (47); it may be localized or diffuse. When localized, it generally points to the site of the abscess. *Okada* found it localized in one-third of the cases he studied, while *Dench* (l. c.), reporting on 102 cerebellar abscesses and 100 cerebral abscesses from recent literature, finds it localized in 71 cases. Too much importance, however, must not be attached to the localization of the headache as marking the site of the abscess.

Pain elicited by percussion of the head is considered as characteristic of brain abscess by *Heine*, *Bergman* and *Macewen*. On the other hand, this sign is often obtained in cases of extra-dural pus collections.

Stiffness at the nape of the neck and pain when bending the head toward the front are somewhat characteristic signs of cerebellar abscess. This symptom is, however often observed in cases of neurasthenia.

Dizziness is observed in both cerebral and cerebellar abscesses. It is especially a sign of the latter. The dizziness is intensified during the exacerbation of the headache, or during the rise of temperature. It may be so marked that the patient will stagger.

This staggering gait is designated cerebellar ataxia. *Jansen* (48) has observed cases of cerebellar abscess where this symptom was entirely absent. The dizziness is often associated with nystagmus.

The sensorium is always affected by the abscess, except possibly during the initial and the latent stages. This clouding of the intellect begins with hardly noticeable deviations from the normal, and becomes toward the end of the disease a profoundly significant symptom. Remissions are common, but the symptom complex from the sensorium reappears with the exacerbation of the fever and the headache. Drowsiness, slow cerebration, retarded speech, inability to work, a disinclination to exertion, loss of memory, restlessness, and finally, during the terminal stage, coma, appears. In some cases, an absolute change in the character of the individual is noted. The patient becomes depressed, melancholic, irritable and sometimes hypochondriacal. In some patients, suicidal tendencies appear, while others become delirious or maniacal; finally they all become comatose and, unless the condition is relieved, they die.

The pulse rate is generally retarded. *Schwartze* (49) speaks of cases wherein it dropped to 44 and 10 to 15 beats to the minute. In some cases, a retarded pulse is observed for but a few days of the illness. In such cases, the pulse rate changes rapidly to the normal, and it may even become accelerated. (Reported by *West*, (51).) A retarded pulse rate is often absent when the abscess is situated in the cerebrum. According to *Köch*, the pulse rate is not dependent on the size of the abscess, and sometimes it remains retarded even after the abscess has been evacuated. According to *Macewen*, there can be no doubt but that the retardation of the pulse rate is due to pressure exerted by the abscess. In support of this contention, he states that after the abscess reaches a certain size, the pulse rate decreases as the size of the abscess increases, and the evacuation, relieving the pressure, brings in its train a sudden increase in the pulse rate. It is to be noted, however, that other intracranial lesions—serious effusions in the meninges and in the ventricles in tuberculous meningitis—produce a similar retarded pulse rate.

Locally, the symptoms from the abscess *per se* are divisible

into two general groups. Those arising directly from the presence of the pus collection in the brain and those which are the distant effects produced by the local brain lesion. In the latter group we classify the symptoms which result from injury to the cranial nerves.

Disturbances of hearing are rare. Interference with speech is found when the abscess involves the speech centers. Then amnesia or optic aphasia, paraphasia, paragraphia, may be noted either individually or in combinations.*

The distant effects of the abscess arise from the increase of intracranial pressure and tension. Spasms, convulsions, tonic cramps of muscle groups, paralyses, hemianæsthesias and hemiopia are uncommon, but are not rare findings.

Among children, the diagnosis becomes extremely difficult, since positive recognition of the various symptoms in the clinical picture is difficult, and other complications of middle ear suppuration, whose symptom complex is similar, are more often present, viz., extradural abscesses, serous meningitis, or brain tuberculosis.

The eye background often shows changes in brain abscess, and although these changes are not absolutely constant, they are present sufficiently often to constitute a significant symptom. The most common sign is a change in the blood vessels of the retina and the disc, usually involving the disc margins; in some cases, marked choked disc is noted. This is generally found in the last stages of the abscess. Following the evacuation of the abscess, the eye symptoms do not at once disappear; they subside gradually; optic nerve atrophy is rare. The only absolute significance to be attached to the retinæ findings are that changes in the background of the eye denotes the presence of some intracranial complication of the otitis. The nature of this complica-

* Definition of Terms: In paragraphia and paraphasia, the patient is found to employ the wrong word to describe a given object. He understands the words correctly, however, when they are written. In amnesic aphasia, the patient fully understands the use to which objects are put, but he cannot properly name them. Parrot-like, the patient is able to repeat the correct name when it is said for him. In optic aphasia, the patient cannot correctly name objects which he sees. Word-deafness is often observed. The patient hears but cannot understand speech. Loss of ability to write is occasionally noted, although the full power of using the hand for other purposes is retained. Sometimes the patients are unable to count.

tion cannot be determined with any degree of accuracy by the examination of the background of the eye.

Among injuries to the cranial nerves, oculomotor paralysis is the most common type of cranial nerve involvement. According to *Körner*, this is almost constantly present in temperosphenoidal abscess. In these cases, however, it is not complete. It involves the sphincter pupillæ, or the levator palpebræ, or both, producing mydriasis or ptosis. The remaining oculomotor nerves are not necessarily involved. Double equal mydriasis has been observed also in cases of rupture of a cerebral abscess into the lateral ventricle.

Paralysis of the hypoglossal and of the facial nerves has been observed, and trigeminal neuralgia has been recorded as due to pressure of the abscess on the intracranial portion of the nerves involved.

In conclusion, it is to be noted that the diagnosis of otitic brain abscess is exceedingly difficult, because its symptoms complex points to practically nothing characteristic, and in addition, is often punctuated by long intervals of remission. Fever, headache, dizziness, vomiting, nystagmus, even differences in the size of the pupils, are often found in the very young in cases of uncomplicated otitis media. Such symptoms are especially observed in such patients when an acute exacerbation is superimposed upon a chronic middle ear suppuration and when in such cases pus retention takes place. Even optic neuritis has been reported. In these young patients all these severe symptoms have been found to subside after pus evacuation has been effected.

Furthermore, fever, headache, dizziness, and nystagmus are likewise the clinical findings of purulent labyrinthitis. A similar clinical picture is seen when intracranial lesions complicate brain abscess, e.g., extradural abscess, meningitis, or sinus thrombosis.

The complete examination of the cerebrospinal fluid obtained from lumbar puncture, and the examination of the blood including an examination for bacteria in the blood may aid in clearing up doubtful cases.

Some Differential Diagnostic Points: When symptoms of an

intracranial lesion become evident, it remains to determine the location and the character of the intracranial process.

Differential Diagnosis Between Cerebellar and Cerebral Abscess: Hemianæsthesia and hemiparesis of the opposite side of the body and sensory and optic aphasia, are suggestive of an abscess in the temporal lobe. It is true that disturbances on the part of the optic nerve are seen in cases of cerebellar abscess, but then the findings present different characteristics. Speech disturbances in cerebellar abscess usually present bulbar characteristics. This is in contradistinction to the findings of sensory and motor aphasias noted in the temporal lobe cases.

On the other hand, when the hemiparesis affects the same side of the body as that upon which the ear disease is located, then it suggests a cerebellar abscess.

Both cerebral and cerebellar abscess present oculomotor disturbances. Ptosis, abducens paralysis, and even oculomotor paralysis are frequently noted in cases of abscess of the temporal lobe. In the cerebellar cases, however, the paralysis more often affects the eye muscles individually.

In cerebellar abscess, conjugate deviation has sometimes been observed. It is of diagnostic significance when combined with nystagmus toward the healthy side.

Neumann (30) saw the eye rotation take place toward the healthy side in four of his cases.

Nystagmus, in cases involving the temporal lobe, although rare, is occasionally observed when the abscess is located far back in the temporal lobe and in close juxtaposition to the occipital lobe.

Headache when localized at the occiput, or at the forehead, suggests a cerebral abscess, when the temporal lobe is the seat of the lesion this symptom is often centralized at the vertex.

Rigidity of the nape of the neck, or tenderness to pressure in this region, suggest the cerebellum as the seat of the abscess. This sign has, however been observed in some abscesses of the temporal lobe, especially when the abscess is very large (*Neumann*).

Differential Diagnosis Between Cerebellar Abscess and Purulent Labyrinthitis: The differential diagnosis between labyrinthine

suppuration and cerebellar abscess complicating a labyrinthine purulency, is of importance mostly as concerns the recognition of the brain lesion. The significant factor in this recognition is played by the determination of the labyrinthine irritability. For this, accurate observation of the direction of the nystagmus, and its increasing or decreasing degree, becomes a necessary factor.

Cerebellar nystagmus may occur toward the diseased side as well as toward the healthy side of the head. It is most commonly observed directed toward the diseased side.

Neumann differentiates the cerebellar from the labyrinthine nystagmus as follows:

1. Assuming that the case presents a nystagmus directed toward the diseased side. This may suggest either a circumscribed labyrinthitis or a cerebellar abscess. If the former labyrinthine irritability, when tested by syringing the wound with cold water, may still be found normal. Examination of the capsule may demonstrate a labyrinthine fistula. Condensation and rarefaction tests call nystagmoid movements into existence. In another group of labyrinthine cases, the irritability of the labyrinth is not demonstrable when the syringe test is made. Nystagmus is, however, still producible by direct pressure combined with galvanism applied to the labyrinth. Under such conditions, the presence of nystagmus gives no diagnostic data of value in differentiating cerebellar abscess from labyrinthine involvement before the surgical examination of the labyrinth. In *Neumann's* clinic, the radical mastoid operation in such cases is followed by the operation on the labyrinth. After the second operation, if the nystagmus now turns toward the healthy side, then it was produced at first by the labyrinthine lesion. In connection with these remarks, it is to be noted that fortunately circumscribed labyrinthitis combined with a cerebellar abscess is a rare lesion. Where nystagmus continues toward the diseased side after the labyrinthine operation, then the probabilities of cerebellar abscess, or at least, disease in the posterior cranial fossa on the same side, are increased. For the destroyed labyrinth is incapable of inducing nystagmus toward its own side of the head. Nystagmus toward the healthy side is induced by the intact labyrinth of the opposite ear.

2. Assuming the presence of nystagmus toward the diseased side, and impossibility to demonstrate labyrinthine irritability. Here, in the face of the behavior of pulse and temperature, the immediate diagnosis of cerebellar abscess is possible, since the nystagmus must be caused by disease in the posterior cranial fossa.

3. Assuming that the nystagmus is toward the healthy side, and the labyrinth is not irritable. This nystagmus may be due to disease in either the labyrinth or in the cerebellum. Differential diagnosis is a most impossible from the nystagmus before the surgical exploration of the labyrinth. After the labyrinthine surgery, the nystagmus will be found to subside within two or three days, if due to abyrinthine causes. When it is the sign of an intracranial lesion, however, it does not subside after the labyrinthine operation, but increases in intensity and degree, and not infrequently it changes its direction and runs toward the diseased side. It is in cases with such findings that the presence of the intracranial lesion becomes positively clear.

Gradenigo's (50) observations substantiate the observations of *Neumann*. He distinguishes between a nystagmus præcox—usually referable to a labyrinthine lesion, and a nystagmus tardres which appears in the symptom complex of intracranial lesions, most often during their terminal stage.

In labyrinthine suppuration, the nystagmus appears early, in the brain lesion its advent is late in the course of the disease.

Differential Diagnosis of Brain Abscess from Meningitis: In the differentiation of cerebellar abscess from meningitis, the behavior of the temperature curve is significant. As a rule, the temperature is high n cases of meningitis. High temperature is occasionally present in the absçess cases, however. Symptoms referable to intracranial pressure may be called forth by a circumscribed meningitis in the posterior cranial fossa as well as by the presence of a cerebellar abscess. Nystagmus, likewise, may be produced by a meningitis involving the internal auditory meatus, the lesion involving the vestibular nerve. Sudden disturbances in the hearing faculty on the healthy side are more likely to indicate a meningitis than a brain abscess. This symptom has however, been observed as a rare finding in cases of

brain abscess. Rigidity of the nape of the neck belongs to the signs of meningitis.

After the meningitis has extended to the convexity, the differentiation is, as a rule, easier. General convulsions, retracted abdomen, the small accelerated pulse, *Cheyne-Stokes* respiration, and total loss of consciousness, clear the diagnosis.

In serous meningitis, the predominating symptom is due to intracranial pressure. Temperature elevations are, however, considerable. Such findings are not uncommon in tubercular meningitis, or thrombosis of the transverse or of the cavernous sinuses.

Severe cerebral symptoms are occasionally observed in simple acute otitis media, accompanied or not by mastoiditis. When these lesions are accompanied by a facial paralysis, by vertigo, nystagmus, vomiting, headache, choked discs, optic neuritis and somnolence, then the differential diagnosis of this lesion from brain abscess is almost impossible before operation. As a rule, such symptoms in cases of uncomplicated otitis media are found only in early childhood.

Differential Diagnosis From Other Diseases: In hysteria, the coincidental presence of otitis media, associated with hemianæsthesia, hemiparesis, vertigo, vomiting and optic nerve disturbances are observed. But the paralysis and the anæsthetic areas in the hysterical cases are present on the same side as the local ear disease, instead of on the opposite side of the body.

The latent period of cerebellar abscess has been confused, with melancholia, with the depression stage of paresis, and also with the depression and vomiting due to the coincidental existence of a suppuration of the middle ear and a pregnancy.

Uræmic states, because of the headache, optic neuritis, vomiting and convulsions, as well as severe infectious diseases, may simulate and be mistaken for the clinical picture of otitic brain abscess when these symptoms occur coincidental to an otitis media purulenta acuta. The findings from lumbar puncture aid in the diagnosis of these doubtful cases.

Indications for Operation: *Bergmann* holds that the otitic brain abscess shall only be operated upon when there are chances

of obtaining good results from operation. That is, when both the locality of the pus accumulation and the certainty of its presence are clearly established.

On the other hand, the discussion of the symptomatology of otitic brain abscess clearly shows the difficulties in many cases of establishing positively the existence of a brain abscess, as well as locating its site.

It becomes, therefore, necessary, in cases giving a suspicious history and an uncertain clinical picture, to await developments for a time. This must not be construed as a recommendation for an extensive period of waiting. In suspected cases, it is always in the interest of the patient to make a systemic search for the pus foci.

Körner (52), *Kretschmann* (53), *Vohsen* (54), *Rose* (55), *Schwartze* (56), and others, have shown the close relationship of purulent foci in the brain and the purulent disease in the temporal bone. The findings at the mastoid operation, when closely studied in connection with the subsequent course of the clinical picture, add additional data and give the surgeon a fairly definite idea regarding the route traveled by the infection toward the cranium.

Furthermore, when the operative findings show the purulent process to have reached the tegmen, perhaps to have become somewhat localized at this point in the form of an extradural abscess, then it is reasonable, in the light of a continued symptom complex, to suspect that the brain abscess is in the temporal lobe. On the other hand, if the operative findings lead the way toward the labyrinth, then a persistence of the symptoms indicate first the eradication of the disease in this structure. When the clinical picture shows no improvement after operation on the labyrinth, then the probabilities of an invasion of the posterior cranial fossa are before us.

In a general way, the direction which the systemic search for purulent foci takes depends to a great extent upon the findings at the first operation of the mastoid and middle ear spaces taken together with the signs of involvement shown by the clinical picture. The probabilities of an abscess or other pus accumulation locating in the posterior cranial fossa, after labyrinthine

involvement, is great, and search must be prosecuted toward this direction for its evacuation (57).

Finally, we hold that no case is too desperate to submit to operation in an attempt to locate and evacuate the pus, as when this is done, even in apparently desperate cases, surprising results are obtained, if the systematic search is successful.

Operation for Abscess Located in the Middle Cranial Fossa: The operat on, to be successful, must not only empty the abscess, but it must also remove the primary disease in the temporal bone. Occasionally, because of the imminence of rupture, the local conditions may necessitate the evacuation of the abscess before the eradication of the disease in the temporal bone. Generally, however, the middle ear space should first receive attention.

There are two methods for approaching and evacuating the abscess:

1. From the skull surface.
2. Through the mastoid wound cavity.

In otological surgery, the second method has been found to be the best, as it permits the evisceration of the disease in the mastoid and in the internal ear at the same time, and permits the surgeon to follow and trace the purulency to the brain, finally, affording a way to remove the intracranial lesion.

From the Skull: 1. After the usual preparation, the skin incision is placed as follows: It commences at the root of the tragus and is carried from that point perpendicularly upward, until the incision reaches the level of the upper edge of the concha. The concha is now turned out of the way, and the incision is carried in a curved line backwards toward the rear of the head, until the posterior boundary of the mastoid process is reached. The direction of the incision now changes, being carried downward for the necessary distance to expose the upper fairly large area. (See Fig. 59. Incision G F E.)

Branches of the temporal artery are necessarily severed and require ligation. The incision often strikes the posterior auricular artery, which must also be ligated.

Retraction of the soft parts follows. This exposes the upper wall of the bony auditory canal and the neighboring landmarks.

The linea temporalis is traced backward from the anterior side of the external auditory canal roof—that is, from the root of the zygomatic process. This line roughly locates the floor of the middle cranial fossa.

The skull is then opened, either by a trephine or a chisel, as near as possible to the designated seat of the abscess. The

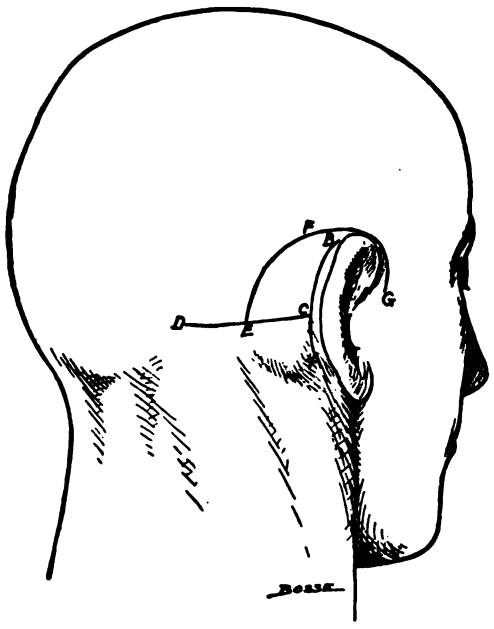


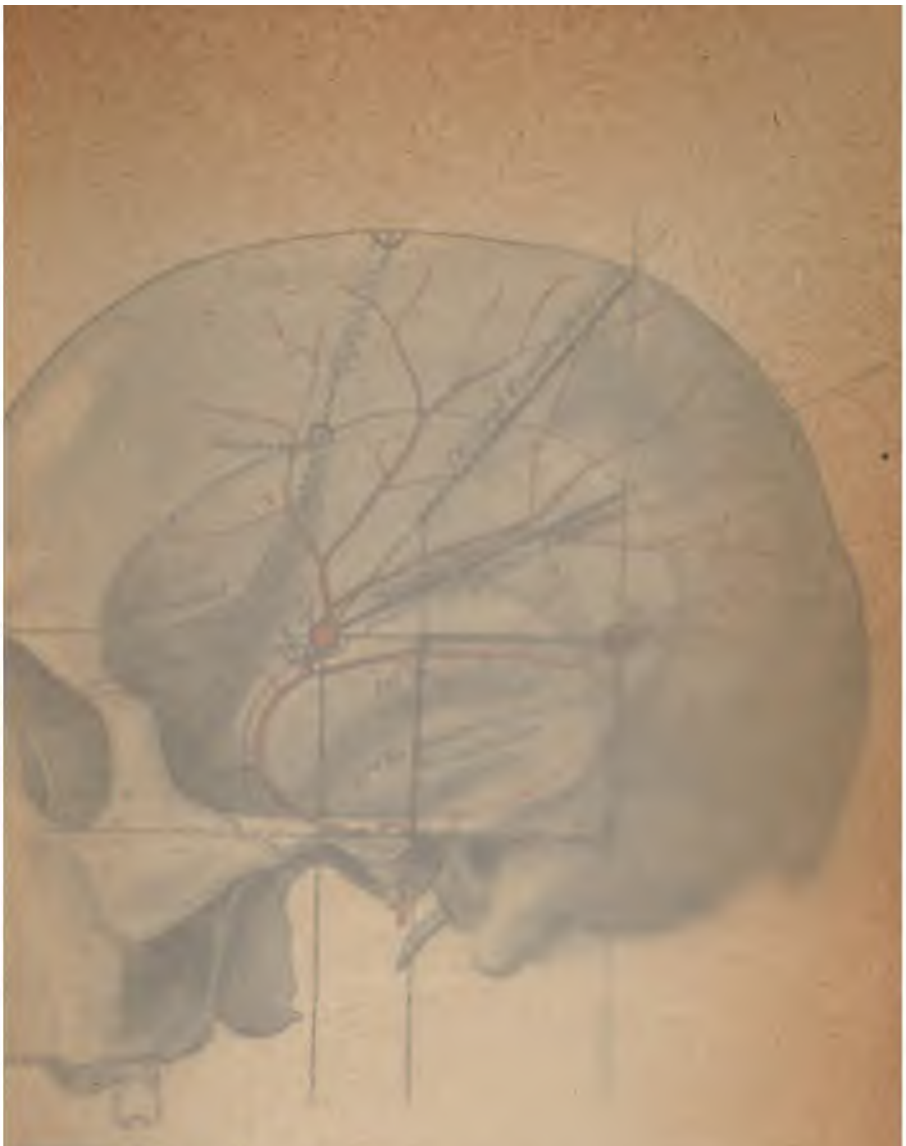
FIG. 59.—OUTLINE SHOWING VARIOUS INCISIONS.

A-B, Usual Mastoid Incision. C-D, Additional Horizontal Incision, Carried Backward, so as to Expose Mastoid Process More Fully or to Permit Tracing the Sinus Back Toward Torcular. G-F-E, Incision to Permit Access to Brain Abscess from the Outside of Skull.

small initial opening is enlarged to expose the underlying dura. Fig. 60 shows the position of the middle meningeal artery and various landmarks which must be kept in mind.

The dura is subjected to minute examination. By enlarging the opening in various directions, exposure for examination of the roof of the middle ear and mastoid spaces is possible.

The opening is freely made, and the brain with intact dura is gently lifted so as to expose the tegmen antri and the roof of the external auditory canal and the tegmen cellulæ matoideæ.



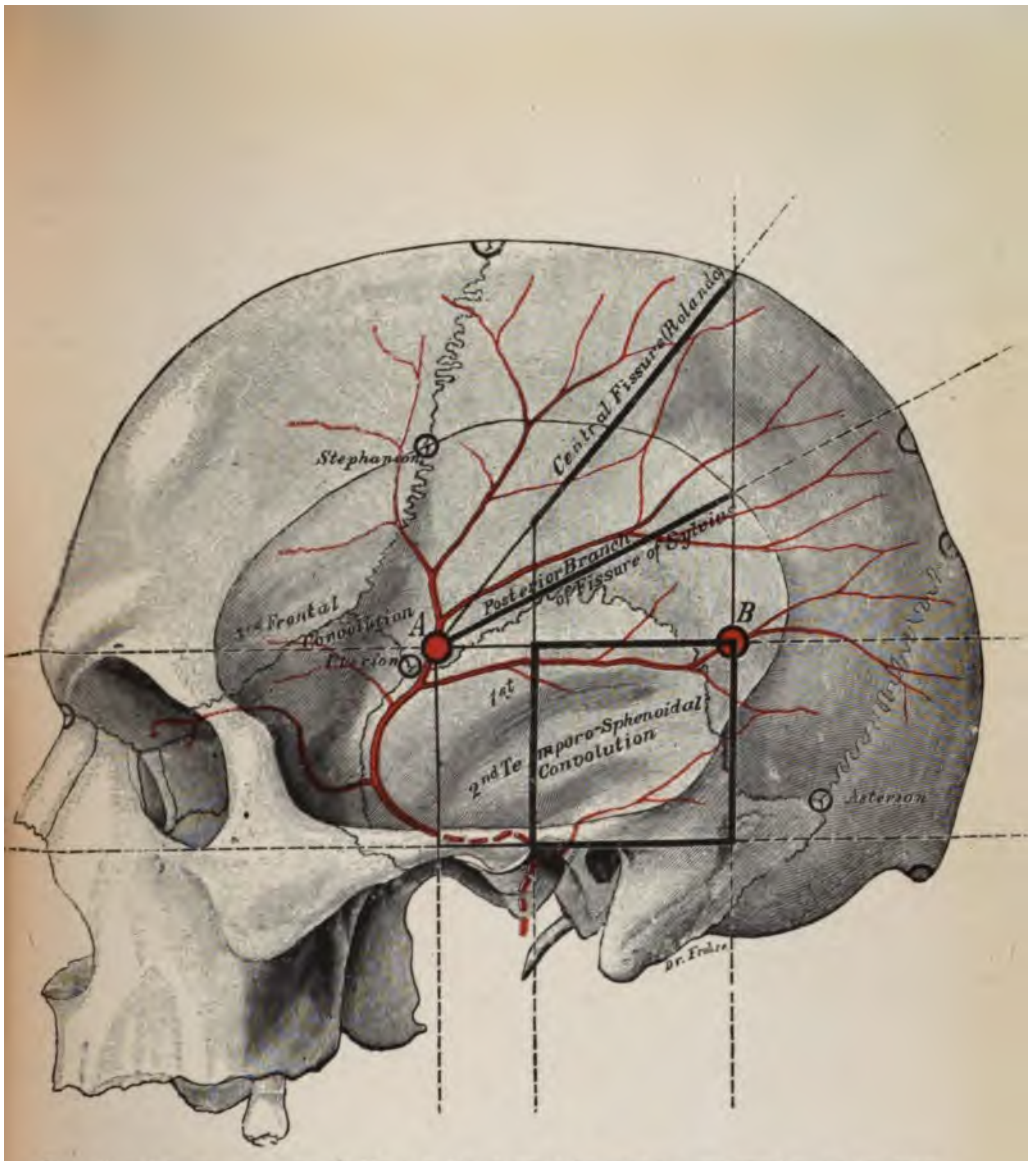


FIG. 60.—PROJECTION OF THE MIDDLE MENINGEAL ARTERY ON TO THE OUTER SURFACE OF THE SKULL.

(With Permission, from Bardeleben's Applied Anatomy.)

The "German Horizontal Line" runs through the infra-orbital margin and the upper border of the external auditory meatus. A second or upper horizontal line parallels the former at the level of the supra-orbital margin. The anterior vertical passes at right angles upward from the 1" horizontal line about the middle of the zygoma. The middle vertical line passes at right angles to the first horizontal, upward, about at the condyle of the lower jaw. The posterior vertical line passes the first horizontal at right angles, being the extension of a line from the posterior margin of the base of the mastoid process. A line connecting A (juncture of anterior vertical and upper horizontal) with extension upwards toward the vertex, gives the general direction of the Central Fissure (*Rolando*). When the angle formed by this line and the upper horizontal is bisected by a line drawn to meet the posterior vertical line, the oblique line represents the fissure of Sylvius. The square marked in thick lines is the region in which *von Bergmann* resects the skull cap to drain otitic abscesses and abscesses of the Tempero-sphenoidal lobe.

It is often possible to see and examine the sinus petrosi superior, and occasionally to see the knee of the sigmoid sinus.

Raising the brain and the dura from the bone upon which these structures rest may, however, injure the sinuses. Furthermore, as *Preysing* (58) has indicated, this maneuver may break down the very adhesions which had kept the pus encapsulated.

The exposed dura over the abscess seat, may appear normal, or the membrane may appear injected, discolored, or covered with granulations. Usually when the opening is made from the exterior of the skull, we find the dura healthy in appearance, because the surgeon is not then working along the route traversed by the disease.

If the abscess is located directly underneath the exposed section of the dura, the absence of pulsations may be noted. Fluctuation can seldom be demonstrated.

The dura which has been exposed, is now incised, following which, the brain substance is entered with a knife. The entrance of the knife should be cautiously conducted. After a penetration has been obtained to 3–4 cm., it is wiser to withdraw the knife, provided no abscess is uncovered. Further search is carried on with a cannula, which should have a rather wide lumen; by pushing it into the temporal lobe in various directions. It must be remembered that the descending horn of the lateral ventricle is sometimes encountered at a distance of from 2½ to 3 cm. from the surface. (See Fig. 61.)

Profuse hemorrhage is controlled by the use of the Pacquelin cautery. Otherwise, general surgical principles are applicable.

2. **From the Mastoid Wound Cavity:** When exploration is undertaken after surgery on the mastoid, that is, after the completion of the simple or the radical mastoid operation, then the whole procedure is simplified.

The tegmen which, during the mastoid operation had been exposed, is now widely opened to bring into view the overlying dura. The dura is found discolored, often covered with granulations, or it is adherent to the brain surface. It may evidence distinct areas of gangrene, which are more or less sharply marked. In rare cases, it is apparently healthy. Usually pulsations are absent.

The absence of pulsations must not be held as affording positive indications for the presence of an abscess for, as *Heine* has pointed out, a deep-seated abscess does not influence the pulsations. Where granulations are present, they are cleaned off. Gangrenous areas are removed or incised.

Where the dura looks healthy, or only discolored, or only sparsely covered with granulations, before incising the dura, test-puncture to locate the abscess, as advocated by *Heine*, may be tried. A thick cannula with a large lumen answers for this purpose.

We prefer to remove the granulations and clean up the entire wound before testing, and usually open the dura by incision first, especially when the symptomatology of the case has fairly well established the existence of the abscess. The dura is split by an incision running from before backward, that is, paralleling the general direction of the temporal lobe. Through the incision thus made, the puncture-test may be performed.

When the exposure of the dura reveals a fistulous opening, puncture test becomes unnecessary.

The abscess located by the needle (see above), the brain is incised with a knife, which is gradually and slowly pushed toward the accumulation of pus. Often as the knife is introduced, the pus comes away along the sides of the blade. It is deemed inadvisable to place the fingers into the wound in the brain. With a little practice, all manipulations are possible by means of instruments.

When the pus has been evacuated, a drain is placed in position, with a slight gauze packing placed around it.

Macewen, *Bergmann*, *Körner*, and others, make a counter opening into the abscess through the squamosal plate. Better drainage and a surer evacuation is thus obtained. This method is especially advocated where the abscess is large and lies some distance from the tegmen or floor of the cranial fossa.

When the counter opening is desired, the second part of the procedure is somewhat similar to that described above for reaching the abscess through the skull, except that the abscess is already located and emptied through the tegmen.

The mastoid incision is extended upward and often somewhat

—Projection of Lateral Ventricle, Middle Ear and Lateral Sinus on the Outer Surface of the Skull.

(From Bardeleben's Applied Anatomy, with Emendations.

ateral Sinus (Violet); Middle Ear Cavities (Red); Lateral Ventricle (Blue).

backward to gain a necessary exposure of the squamosal plate. This plate is then penetrated and the opening thus made is enlarged. The dura underlying this plate is thus exposed and is incised, after which the adjacent brain substance is opened down to the abscess. This provides the counter opening of the abscess to the entrance already obtained through the tegmen.

When this method is employed, drains are also introduced through this second opening.

The advantage of opening the abscess from the tegmen lies in the fact that we open the abscess at a point where gravity favors drainage, and we surgically follow to its seat the pathological process from the middle ear spaces, eviscerating all evident disease as we advance. Furthermore, in this way, we are less likely to break down protecting barriers, and hence we lessen the danger of a subsequent general meningeal infection.

Operation for Evacuation of Cerebellar Abscess: There are two ways of approaching a cerebellar abscess. The uncertainty of diagnosis, and the knowledge we possess of the routes of cerebellar invasion, makes the exploration of the posterior cranial fossa easier when undertaken from the interior of the mastoid wound than when we attempt to approach the lesion from the skull surface.

The exposure of the cerebellar dura begins by laying the sigmoid sinus free, at a point somewhat near the sinus knee, and working downward on the descending portion of the sinus.

Internal to the descending dural sinus wall, we remove the inner mastoid table. If a necrotic area, or opening on the inner table is evident, then this points the way toward the cerebellar dura which is involved.

When removing the inner mastoid table, we limit our procedure at the level of the inner antral wall. When the anterior cerebellar surface is to be uncovered, then the inner antral wall offers the best route to its exploration. When the cerebellar dura has been uncovered, subsequent procedures—its examination; its incision; puncture of the cerebellum, location of the abscess; and finally, the evacuation and the drainage of the abscess cavity, proceed along lines indicated for the surgical treatment of the temporal lobe abscess.

of obtaining good results from operation. That is, when both the locality of the pus accumulation and the certainty of its presence are clearly established.

On the other hand, the discussion of the symptomatology of otitic brain abscess clearly shows the difficulties in many cases of establishing positively the existence of a brain abscess, as well as locating its site.

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Körner (52), *Kretschmann* (53), *Vohsen* (54), *Rose* (55), *Schwartze* (56), and others, have shown the close relationship of purulent foci in the brain and the purulent disease in the temporal bone. The findings at the mastoid operation, when closely studied in connection with the subsequent course of the clinical picture, add additional data and give the surgeon a fairly definite idea regarding the route traveled by the infection toward the cranium.

Furthermore, when the operative findings show the purulent process to have reached the tegmen, perhaps to have become somewhat localized at this point in the form of an extradural abscess, then it is reasonable, in the light of a continued symptom complex, to suspect that the brain abscess is in the temporal lobe. On the other hand, if the operative findings lead the way toward the labyrinth, then a persistence of the symptoms indicate first the eradication of the disease in this structure. When the clinical picture shows no improvement after operation on the labyrinth, then the probabilities of an invasion of the posterior cranial fossa are before us.

In a general way, the direction which the systemic search for purulent foci takes depends to a great extent upon the findings at the first operation of the mastoid and middle ear spaces taken together with the signs of involvement shown by the clinical picture. The probabilities of an abscess or other pus accumulation locating in the posterior cranial fossa, after labyrinthine

almost immediately. Packing the cavity firmly with gauze is, therefore, not recommended. A few strips of plain gauze placed about the drain are usually all that is required.

When the cavity is of large size, and has well-developed walls a very light packing with iodoform gauze may be used.

A strip of gauze is then introduced into the counter opening, around a soft rubber drain. In selected cases we may dispense with this; when employed the gauze is pushed through the counter opening to the upper end of the first opening which leads to the mastoid wound.

The mastoid wound is dressed separately. The skin may be drawn over the counter opening by purse-string sutures which subsequently are drawn tight as the necessity for counter drainage disappears. Or the method advocated by *Barnhill* (59) may be employed. This is applicable when the parts are not too mutilated or diseased. He advises that the flap of dura and the skin be stitched into proper place, using interrupted catgut sutures. He arranges his packings so that none of the gauze drain extends beyond the dura at the counter opening. Subsequent dressings are made only through the opening in the tegmen. The suture lines are covered with boracic acid powder.

The mastoid wound is dressed, and a large quantity of loose gauze placed over the wounds, taking up the drainage tubes from the abscess cavity. A retention bandage holds the whole dressing in place.

After-treatment: The opening and the evacuation of the abscess does not necessarily guarantee a recovery. The after-treatment is as important a factor in the recovery as the successful evacuation of the pus. The possibilities of the subsequent development of purulent meningitis must be borne in mind. This usually results because sufficient drainage from the wound has not been provided The formation of adhesions about the brain wound often tends to cause too early healing, and after pus retention of some degree again becomes established, the symptoms reappear, necessitating reopening the cavity.

This is avoided by using a thick, soft rubber drain with a wide lumen, around whose edges gauze is placed to prevent irritation of the cavity's walls.

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short duration, their disappearance may be prompt or gradual. Improvement is, however generally noticed at once.

Pain will be absent, and the patient not only takes but retains nourishment; the return of appetite is generally a significantly good sign. Cerebration is again alert and, in fact, those who have observed the sudden changes for the better in such patients can hardly realize the amount of brain tissue that was involved in the pathological process.

Results of the Operation: *Macewen* reports that he operated upon nine cases of temperosphenoidal abscess with eight recoveries. The case which died was operated upon while *in extremis*. Of cerebellar cases, he operated upon four, all of which recovered.

The majority of cures are obtained in cases where the abscess was opened both through the cortex and through the mastoid wound.

Körner reports for this procedure, as follows: In cerebellar abscesses, the cures amounted to 66.6%, and in the cerebral cases to 84.6%, of the cases published in literature.

Räpke (61) finds that 40.4% of the cases gave permanent cures. His study of the results of the surgery of these cases was made after the lapse of considerable time after the first reported cures. This placed him in a position to judge the permanency of the cures, and caused him to modify the figures usually obtained from the published statistics.

After Effects of the Abscess: Unpleasant after effects of otitic brain abscess are to be expected as a result of trauma endured by the brain; and from the persistence of paralysis or aphasias; and from the occurrence of the brain hernias and the loss of brain tissue.

Lucae (62) reports a case of paranoia hallucinatoria, and *Räpke* reports that in ten healed cases some kind of cerebral disturbance persisted for a long time. In only two of these ten cases, however, were these disturbances permanent.

Brain hernias, by permanently fixing the brain at some point, even when the brain tissue does not protrude beyond the confines of the mastoid cavity, subjects the brain to a succession of shocks during sudden jars or quick turnings of the head. This

may produce attacks of dizziness or sudden loss of consciousness. Such observations have been made. The seizures occasionally simulate epileptiform attacks.

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CHAPTER XII

PARALYSIS OF THE FACIAL NERVE

General Considerations—Diagnosis; Prognosis—Choice of Nerve for Anastomosis—When to Operate—Varieties of Anastomosis—Operation of Facial Accessory, and Facial Hypoglossal Anastomosis—Technical Points—After-treatment—Results.

General Considerations: Facial palsy occurs independently of, or incidentally with ear disease, or it is the result of an affection of the ear. As a result of disease in the ear, it follows an involvement either of the middle ear spaces or of the labyrinth; or it is the result of trauma, due to surgical manipulations.

When incidental to ear disease, facial paralysis has no obvious connection to the disease of the ear, and therefore, this form of facial paralysis is not discussed here. When the palsy is the result of ear disease, facial paralysis is most commonly observed in connection with chronic middle ear suppuration, although occasionally, it is found as the result of an acute middle ear involvement. This latter condition is observed mostly in children.

Pressure exerted by the accumulation of purulent exudate in the tympanic cavity is a frequent cause of facial palsy. This produces a perineuritis or a neuritis (often seen in the acute cases). In these cases dehiscences in the contiguity of the bony encasement of the nerve are suspected.

In the chronic cases of middle ear suppuration, the paralysis results from the encroachment of the carious or necrotic process upon the encasement of the facial nerve, the nerve itself being finally involved. This type of involvement is commonly found in tuberculous disease of the temporal bone; the continuity of the nerve is generally destroyed in cases of this character.

In cases of acute involvement of the internal ear, facial palsy results from the advance of the pathologic process to the nerve

at the bottom of the internal auditory meatus. I have observed early facial paralysis occur as the first sign of labyrinthine purulency in cases among children.

Facial paralysis is occasionally, the direct result of surgical procedures upon the middle ear spaces. The manipulations necessary to remove impacted foreign bodies from the auditory canal, often cause an inward migration of the ossicles, and consequent impingement of one or other of the processes of the incus upon the nerve. While such accidents are not always avoidable, the open post-auricular method of removing foreign bodies presents less dangers to the facial nerve than intrameatal procedures; but even with the open method, the nerve is sometimes unavoidably injured.

During the performance of ossiculectomy, the nerve is liable to injury, by the instruments, or during the extraction of the incus. Reasonable care, coupled with a knowledge of the technique of this operation, makes the accident a rare occurrence.

The facial nerve is relatively more frequently injured during the performance of the radical mastoid operation. The injury usually occurs during the removal of the posterior meatal wall, when the mastoid wound cavity is connected with the tympanic cavity. Here too, exact knowledge of the surgical anatomy of the facial, and of the technique of mastoid surgery, minimizes the dangers to the nerve. (See Fig. 62.) Occasionally, the conditions found at operation are such that they justify the cautious removal of necrotic bone so close to the facial nerve that this structure may be injured. The surgeon must weigh the chances of recovery from the mastoid disease against a possible facial paralysis, and govern his actions by the conditions found.

In the surgery upon the labyrinth, the facial nerve is frequently injured. In these cases we must not proceed too cautiously, as failure to eradicate a labyrinthine purulency is generally fatal.

In infancy, the superficial point of emergence of the facial nerve must be borne in mind; in making the first skin incision, as the knife may sever the nerve at its point of emergence from the skull.

Finally, where deficiencies in the bony encasement of the facial

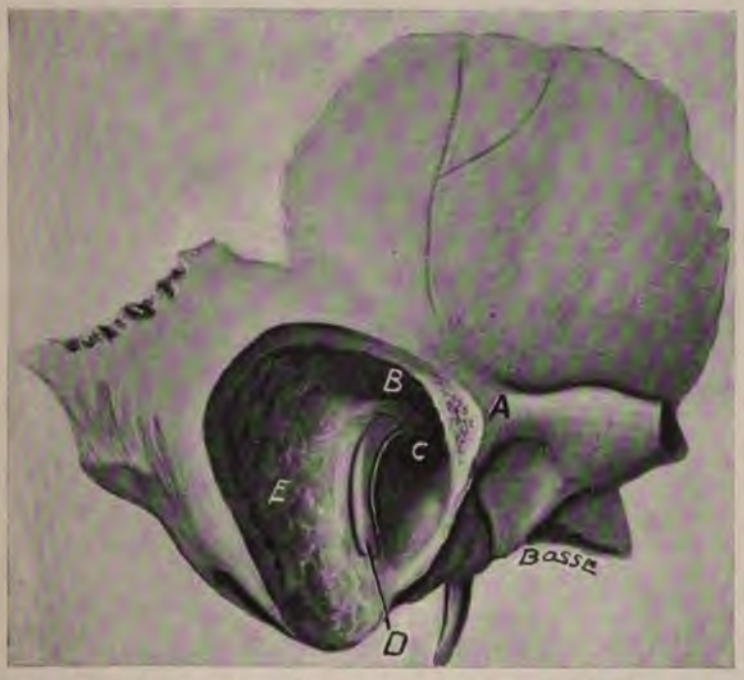

FIG. 62.—THE FACIAL NERVE EXPOSED BY THE COMPLETE REMOVAL OF THE OSSEOUS POSTERIOR MEATAL WALL TO SHOW ITS RELATION AND GENERAL DIRECTION IN THE RADICAL MASTOID WOUND CAVITY.

A, Zygomatic Root. B, Aditus ad Antrum. C, Tympanic Cavity. D, Facial Nerve. E, Inner Table of Mastoid.

PLATE XX.

nerve exist, extravasations of blood or pressure from a tampon may produce facial palsy. The paralysis then occurs some time after operation, and is generally cured by removing the exciting cause.

Summarizing, we find that the facial nerve may become involved because of bony dehiscences in the Fallopian canal, or through destruction of the canal by purulent processes, by pressure of cholesteatomatous masses, by pus retention, or labyrinthine involvement; or the palsy may result directly from surgical trauma.

To complete the list of causative factors of facial paralysis, fracture of the base of the skull, purulent meningitis extending from the meninges to the internal auditory meatus and there involving the nerve; and pressure paralysis from the existence of cerebral abscesses or tumors, are to be remembered.

Diagnosis: In every case of facial paralysis, a complete functional and otoscopic examination of the ear is indicated. Absence of objective ear symptoms and normal hearing demonstrate that the facial paralysis is not of otitic origin. If ear disease is present, the determination of the cause of the facial paralysis is a more difficult problem. The diagnosis must solve the question as to whether or not the facial paralysis and the ear disease stand in causal relation to each other. Generally speaking, otitic facial paralysis is of the peripheral type.

It is often of importance to be able to locate the seat of the nerve lesion. If this is located between the branch to the stapedius muscle and the point of emergence of the nerve at the stylo-mastoid foramen, then disturbances in the sense of taste, with diminished activity of the salivary glands on the affected side, are noted. These phenomena are accounted for because of involvement of the chorda tympani nerve in the paralysis.

When the lesion is located above the point where the branch of the stapedius is given off, and below the geniculate ganglion, in addition to the symptoms above described, there will be found a marked tinnitus (accompanied by some degree of deafness), together with an increased capacity for hearing low-pitched notes. These findings are ascribed to the resultant paralysis of the nerve to the stapedius muscle.

When the lesion involves the facial centrally to the geniculate ganglion, disturbances of taste are absent, because the chorda tympani leaves the geniculate ganglion through the superficial petrosal to join the fifth nerve. (*Tod*, 1.)

Prognosis: The prognosis depends upon the causative factor; this is especially true in the non-otitic types of facial palsy. If the paralysis is due to middle ear suppuration, i.e., to pus retention, recovery usually follows evacuation and drainage of the tympanic cavity.

In chronic cases, the recovery depends upon the duration of the pathological process, and the amount of damage the nerve has sustained.

The determination of the presence of the reaction of degeneration is important in arriving at the prognosis. If a reaction of degeneration is present, recovery is doubtful. When recovery does take place, it is generally slow.

In cases where facial paralysis immediately follows the operation, as a result of injury by the chisel or curette, recovery may follow, provided the severed nerve ends are brought into intimate contact, or where they are left in apposition after the injury. Here recovery takes place spontaneously provided no granulation tissue intervenes between the cut ends of the nerve.

Where the paralysis occurs after a lapse of time, recovery will take place ultimately, if the exciting cause is removed, and provided the paralysis does not indicate an involvement of the labyrinth.

If sections of the nerve are destroyed by implication in the necrosis, then the paralysis is permanent. This is usual in tubercular lesions. Finally, surgical trauma generally destroys sections of the nerve with resultant permanent facial paralysis.

For these permanent forms of palsy a technique has been devised, whereby the peripheral end of the paralyzed nerve is joined to the central end of a neighboring healthy nerve, in order to regenerate the terminal branches of the paralyzed facial, and restore the muscles of the face to activity.

Ballance, of England, first performed anastomosis of the facial, using the spinal accessory. He performed his first operation upon the human subject in 1895. Since then, many others

(see *Taylor* and *Clark*, (2),) have performed anastomosis of the facial with the spinal accessory, and the hypoglossal nerve.

Choice of Nerve: The spinal accessory is easily reached and easily approximated to the distal end of the paralyzed facial. The loss of function which follows section of this nerve—inability to raise the arm above the horizontal—is unimportant and gradually disappears. A noticeable drooping of the shoulder, with a partial atrophy of the sternomastoid and the trapezius, is permanent. Thus it is seen that the loss of normal function from severing this nerve trunk is not of moment. These considerations constitute the advantages claimed for the spinal accessory.

On the other hand, objections have been found to the employment of the accessory because, in certain cases, movements of the shoulder were found to be associated with movements of the face muscles and vice versa (*Woolsey* (3), *Taylor* (2), *Cushing* (4).) Exceptions to this finding of associated movements are recorded by *Mintz* (5) and *Elsberg* (6), and although an entire dissociation of movement is rare, partial dissociation does take place after the cortical center of the spinal accessory has been educated to its new function. A considerable lapse of time is necessary for this to become established.

Taylor and *Clark* state that during the last three years, the hypoglossal has been chiefly used for anastomosis with the facial. This nerve has the advantage of being anatomically and physiologically in intimate relationship with the facial at their central extremities in the brain. *A priori*, it appears easier to educate the hypoglossal center to take on the functions of the facial. According to *Woolsey*, the disadvantages of the spinal accessory are the advantages of the hypoglossal. *Alfred Taylor* favors the hypoglossal as affording the best results. He believes that the end-to-end anastomosis should not be performed, but that the distal end of the facial should be implanted by lateral implantation into the hypoglossal. This procedure seems to give the best results, avoiding even the palsy to the tongue.

The use of the hypoglossal by end-to-end anastomosis results, in a paralysis with atrophy of one half of the tongue. This naturally affects speech, and in the beginning there is observed interference with the act of swallowing. This is a

end-to-end method, or by a procedure known as lateral implantation.

End-to-end anastomosis necessarily sacrifices the peripheral end of the healthy nerve with consequent paralysis of its muscle field. On the other hand, it is easy to carry out and requires less skill than lateral implantation.

In end-to-end anastomosis, the peripheral end of the paralyzed facial, or a large segment of it, is approximated to the central end of either the hypoglossal or the accessory. Instead of using the entire central end of the intact nerve, a large segment of this nerve may be employed. This is the procedure most commonly employed in the facial anastomosis.

Lateral implantation does not necessarily sacrifice the entire function of the healthy nerve. The peripheral end of the paralyzed facial is implanted in a longitudinal slit or niche made in the intact nerve. This method, although more difficult in technique, saves the muscle field of the healthy nerve from paralysis, and is the procedure which is advocated for these cases.

Facial-Hypoglossal and Facial-Accessory Anastomosis: The operation begins by making an incision into the skin and subcutaneous fascia, along the anterior border of the sternomastoid muscle. The incision commences about 2 cm. above the mastoid tip, and is carried downward along the muscle margin to a point level with the upper border of the thyroid cartilage. Bleeding vessels are clamped, and if necessary, ligated.

The sternomastoid muscle is now exposed by a blunt dissection; the posterior margin of the parotid is then also in view. The separation of the posterior edge of this gland from the surrounding tissue then ensues. The gland is pulled forward, and the sternomastoid muscle backward. The facial nerve is now sought. It is generally found at its point of entrance to the parotid, about 1 cm. above, and 1 cm. internal to the mastoid tip. (See Fig. 63.)

Duel and *Frazier* (12) have suggested removing a small amount of the mastoid tip to expose a greater amount of the nerve trunk, a suggestion which *Taylor* tried and finds the surest and quickest way of obtaining a requisite length of nerve trunk. Furthermore, when difficulty is experienced in locating the

nerve, the skin incision may be carefully deepened, cutting into the posterior border of the parotid gland. Gentle separation of the severed parts usually will reveal one or other of the chief branches of the facial. From the branch thus located, the nerve

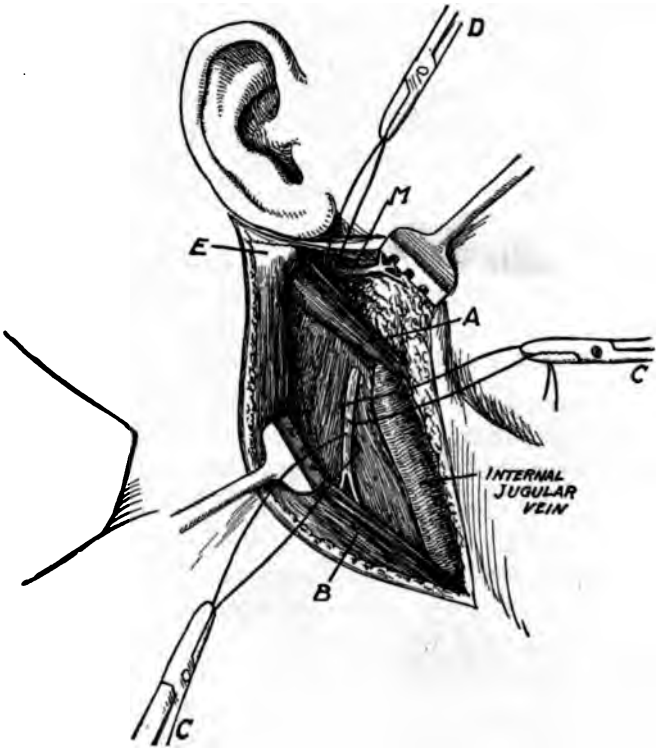

FIG. 63.—GUIDE TO FACIAL ACCESSORY ANASTOMOSIS.

A, Digastric Muscle. B, Sternomastoid Muscle Pulled Aside. C, Clamp on Suture Passed Through Spinal Accessory Nerve. D, Sutures in Facial Nerve (M). E, Mastoid Tip. (After Cushing.)

trunk may be found by tracing the branch backward to its parent trunk. (Fig. 63.)

The trunk when located, is raised upon a blunt hook or other suitable instrument, and two fine silk sutures passed through its sheath, just beyond the site at which it is determined to sever the nerve trunk. Necessarily, the nerve should be cut as close to the stylomastoid foramen as it is possible to go.

If the amount of nerve trunk obtained is insufficient to effect an anastomosis the removal of mastoid bone tissue will free a greater length. The nerve trunk with the sutures in position is then placed to one side, until the nerve selected for the anastomosis has been located and properly prepared. The subsequent procedure varies according to the nerve selected.

If an anastomosis with the hypoglossal is desired, the dissec-

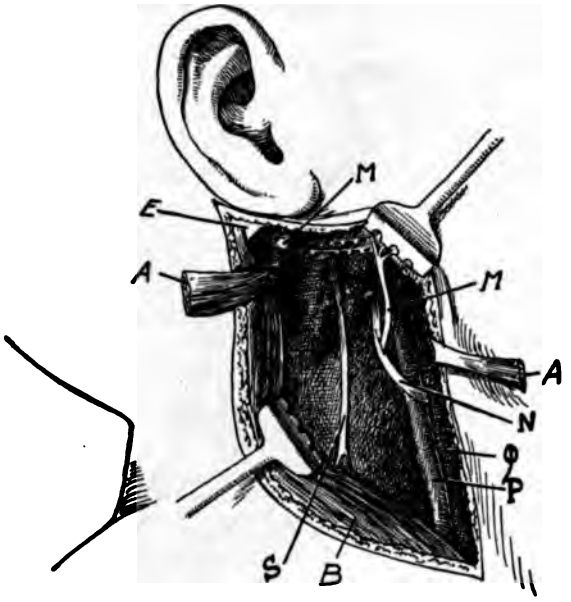

FIG. 64.—LATERAL IMPLANTATION OF THE DISTAL END OF THE FACIAL NERVE (M), INTO THE HYPOGLOSSAL NERVE (N). (TAYLOR'S METHOD.)

A, Cut Ends of the Digastric Muscle. B, Sternomastoid Muscle. E, Remmains of Mastoid Tip. M, Facial Nerve. (Dotted Line Showing Original Course of Nerve.) N, Hypoglossal Nerve. O, Internal Jugular vein. P, Carotid Artery. S, Spinal Accessory Nerve. (Partly Schematic.)

tion into the deep fascia continues. The occipital artery and the posterior belly of the digastric are guides to this nerve. The hypoglossal nerve is found in the deep fascia as it curves under the occipital artery to cross the external carotid artery. (See Fig. 64.)

The hypoglossal is carefully separated from the surrounding tissue until sufficient length is obtained to permit an easy approximation with the peripheral end of the facial. Fine silk

sutures are now passed through its sheath. These are used to steady the nerve during the subsequent maneuvers. If end-to-end anastomosis is to be performed, the nerve is cut with a sharp knife, just beyond the sutures, and the central end of this nerve is sutured to the peripheral end of the facial by means of four fine silk sutures passed only through the nerve sheath.

Where lateral implantation is to be tried, the hypoglossal is suitably supported, and a horizontal, or rather a longitudinal,

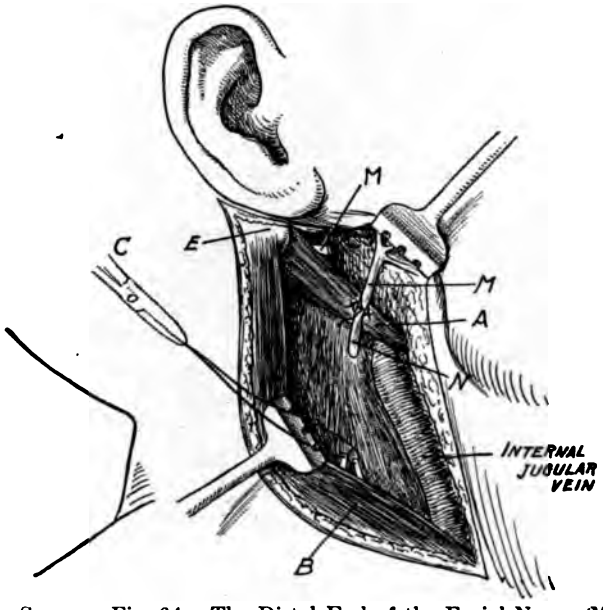

FIG. 65.—Same as Fig. 64. The Distal End of the Facial Nerve (M) is Cut and Turned to Meet the Cut End of the Spinal Accessory Nerve, to make an end-to-end Anastomosis. The clamp C, Holds the Distal End of the Spinal Accessory Nerve. (After Cushing.)

slit is made in its sheath, into which the peripheral end of the facial nerve is grafted. One or two fine silk sutures fasten the graft into position.

If anastomosis is to be made with the spinal accessory, this nerve is sought. This is easy of accomplishment. The nerve is generally located about 5 cm. below the mastoid tip, at which place it enters the sterno-mastoid muscle. It lies just beneath the deep fascia, the transverse process of the atlas serving as a guiding landmark. The nerve is covered by the posterior belly

of the digastric and lies directly below the transverse process of the atlas. (See Fig. 65.)

Silk sutures are passed through the nerve sheath, and it is severed at a point just proximal to the suture, when an end-to-end anastomosis is to be made.

Sometimes the anastomosis is made over the belly of the digastric, or, as performed by *Mintz*, this belly may be divided to facilitate the anastomosis. *Villar* (13) made the anastomosis underneath the muscle.

Where lateral implantation is desired, the technique is similar to that described above for lateral implantation of the hypoglossal.

Points in the Technique: Fine curved, round needles should be employed. The sutures should be placed before the nerve is divided. The nerve stumps should not be handled, except by means of these silk sutures.

The nerve trunks must never be divided with scissors, but by a sharp knife. If the ends of the facial nerve are found diseased, before suture, they must be freshened, using a sharp knife for the purpose.

After exposure of the nerves, care should be exercised to minimize the trauma to which the nerves are subjected. They must not be handled with the forceps, but by perineural sutures, introduced before the nerve is cut. During the entire procedure, perfect asepsis is necessary for the successful issue of the operation.

After-treatment: Following the completion of the anastomosis, Cargile membrane may be wrapped around the point of anastomosis, to prevent the ingrowth of connective tissue, or the formation of adhesions.

The remainder of the wound may be closed at once, or the suture of the wound may subsequently be done, omitting the Cargile membrane from the dressing.

During the entire period, as near perfect asepsis as possible is a necessity.

Further after-treatment, consists in massage of the facial muscles, stimulation of their tone by electricity, at first by means of the galvanic current and later with faradism.

Results: The results of anastomosis of the facial are encouraging, but as *Woolsey* remarks, the operation is still of too recent

date and its technique still too unsettled to permit of a large statistical review.

In view of the benefits to be derived from its successful performance, it should at least be tried, rather than to doom cases to a lifelong facial paralysis.

Results are found to vary somewhat with the age of the patient, the duration of the paralysis, the method of anastomosis employed, and the degree of asepsis and the mastery of the difficult technique.

Mintz reports seven failures among twenty-two anastomoses.

Which form of anastomosis and which nerve trunk should be employed remain, in the present state of our knowledge, an open question.

The successful outcome of an anastomosis is the restoration of normal function and the restoration of the symmetry of the face in repose. This is the first result to be expected. If improvement continues, voluntary control of the facial muscles is acquired, enabling the patient to close the eye in winking, pucker the muscles of the mouth, etc. A complete recovery demands restoration of the function of movements in the muscles of expression and emotion. This is hardly to be expected, however.

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CHAPTER XIII

LUMBAR PUNCTURE*

As an Aid to Diagnosis—As a Therapeutic Measure—As a Procedure to Produce Anæsthesia—Technique of Lumbar Puncture.

Lumbar puncture has aroused a wide discussion, both as a therapeutic measure and as an aid to diagnosis since its introduction into medicine by *Quincke.*

In the succeeding, we have endeavored to collect authoritative opinions, classify and arrange them, in order to give a general résumé of a subject which, when properly placed and intelligently used, is of great value to otology.

The subject resolves itself into the consideration of lumbar puncture from three distinct view points:

I. As an aid to diagnosis.

II. As a therap utic measure.

III. As a procedure to produce anæsthesia.

1. As an Aid to Diagnosis: From an originally empirical procedure, lumbar puncture has developed into a highly scientific exploratory method. The chemical and bacteriological character of the spinal fluid has been studied with great care in Germany. The practical value of this diagnostic measure was enhanced in France by applying to the fluid the method known as cytodiagnosis of *Widal, Ravaud,* and *Sicard* with its greater precision and more definite formulæ.

In contradistinction to the bacteriological examination of the cerebrospinal fluid with its direct demonstration, cultures, and animal inoculation, the cytodiagnostic or histological method consists in the microscopic determination, in the obtained fluid

* This chapter is written from material used in an article on lumbar puncture, published by the author in the *American Journal of Medical Sciences,* April, 1906.

as withdrawn, or after centrifugation, of the several varieties of leucocytes which are differentiated in accordance with their morphology and their staining affinities. The cytological formulæ established by *Sicard, Widal,* and *Ravaud* express the practical application of the histological method.

The bacteriological and the cytological examination were soon extended by cryoscopy (*Widal, Sicard,* and *Ravaud*), chromodiagnosis (*Sicard*), chemical analysis applied to certain forms of meningitis (*Sobrazes, Deniges,* and *Wulf*), and finally the study of meningeal permeability, etc.

Essential points in the technique of the examination of cerebrospinal fluid are:

1. The pressure under which it is obtained.
2. Its coloration (chromodiagnosis).
3. The bacteriological findings.
4. Cytodiagnosis.
5. The chemical examination.
6. Cryoscopy of the fluid.

Normal cerebrospinal fluid is a clear transparent liquid, with a specific gravity of 1003 to 1004 (*Archard* and *Laubry* (79),) and usually of a quantity varying from 60 to 100 grams, which is sometimes increased to 300 and even 400 grams in the aged. Under abnormal conditions the color is often altered, and the specific gravity varies from 1002 to 1009 (*Archard, Laubry*).

1. *Pressure.* The degree of pressure under which the cerebrospinal fluid is obtained is easily recognized without instruments by the strength of the spurt and the height of its curve during withdrawal. Slow evacuation, drop by drop, indicates hypotonia, while a fountain spurt, the patient in a recumbent position, gives evidence of a rise of pressure. Pressure is subject to considerable vacillation in the same patient, and during the same posture, depending upon the position of the head, cardiac pulsation, and respiratory activity. (*Reiken* (56).)

According to *Quincke,* pressure rises in grave inflammatory conditions, in tuberculous meningitis, and in brain tumor; the highest observations recorded are those in tuberculous meningitis and acute hydrocephalus.

Lermoyez (57) noted a behavior of the puncture liquid, simu-

lating a urinary stream issuing under strong pressure, in a case of brain abscess of otitic origin.

The diagnostic importance of pressure is on the whole a limited and secondary one. *Heiman* (157), in a recent publication places great diagnostic value on the pressure under which the fluid is obtained, and advocates the use of a manometer for estimating this pressure.

2. *Coloration.* For the summary of characteristics obtained from the coloration of the cerebrospinal fluid, *Sicard* proposes the name "chromodiagnosis." He considers this part of the examination as very reliable and instructive. Unfortunately the cases with distinct modification of color are usually the least obscure clinically.

Wentworth (58) suggests careful comparison of the fluid received from spinal puncture into a test tube with distilled water contained in a similar tube. The normal appearance may be altered by accidental or pathological admixture with blood or micro-organisms. Blood is easily recognized. Leucocytes contained in the fluid cause a characteristic turbid appearance, although there is a record of an observation by *Braunstein* in which the fluid was cloudy without hyperleucocytosis or other formed constituents (probably as a result of unrecognized chemical changes).

In a general way coloration is affected in acute meningeal inflammations, exceptionally in these conditions the fluid may remain clear.

The discoloration varies from almost clear to a general yellow, and from the slightest trace of cloudiness to a well-defined purulent turbidity in cases of acute bacterial meningitis. In chronic meningitis the fluid will generally be found clear, but occasionally it presents a greenish-yellow color. (*Raymond, Widal.*) In tuberculous meningitis *Widal* found it usually clear, sometimes opalescent; on the other hand, *Wentworth* always found it more or less cloudy. It was clear in only 5% of the cases of *Bernheim* and *Moser* (60). From admixture with pigment derived from bile or from blood serum it may present a yellowish or greenish-yellow color in cases of icterus. (*Widal, Sicard,* and *Ravaud* (61).)

So much variability in the coloration of the fluid has been observed by *Foster* (59) that he places no faith in the data obtained from the color examination.

3. *Bacteriological Findings.* The bacteriopathology of puncture fluid has been extensively studied since the introduction of the method. Nearly all forms of micro-organisms have been found in it, for there may be a mixed infection, with other bacteria than those pathognomonic of the disease in any given condition. Diplococci are especially common in affections of the spinal meninges, but true gonococci are rarely found. *Weichselbaum's* diplococcus intracellularis, the accepted cause of cerebrospinal meningitis, if found, settles the diagnosis in this disease. This is generally demonstrated without difficulty, and may be distinguished by culture methods from the micrococcus catarrhalis, which is much more easily grown in lower temperatures and on all kinds of culture media. In otogenic infections arising from a pathological process in the region of the ear there may be no micro-organisms at all in the cerebrospinal fluid. (*Hastings* (80).)

Kroenig (81) demonstrated granular detritus nerve fibers containing myeline, free myeline, and blood crystals in the bacteriological findings of the spinal fluid.

He examined the fluid from four cases during life which later came to autopsy, and his diagnosis previously made by puncture of cerebral foci of softening with rupture into the subarachnoidal space was borne out by the post-mortem findings.

In the fluid withdrawn from hemiplegics the signs of older hemorrhages into the brain substance or the meninges were demonstrated in the form of hæmatoidin and hæmosiderin. The finding of these latter in the fluid might be of eventual value in the differential diagnosis between embolism and hemorrhages. He was never able to demonstrate tumor elements, although he once was able to diagnose a rupture of a brain tumor, which was confirmed at autopsy, from the detritus found in the puncture fluid.

Bacteriological examination includes direct investigation, cultures, and inoculation. Cytological diagnosis does not exclude bacteriological examination. The bacteriological test

made directly and by culture may be performed at the bedside. (*Sicard* (62).)

The direct examination is made according to laboratory methods in common use for research work of this kind. *Stadelman* has shown that bacteriological findings, notably of the tubercle bacillus, depends largely upon the worker's skill, consequently he considers only positive findings of diagnostic value.

In acute cases where the medical or therapeutic interference must be prompt on account of imminent danger to life the direct examination is the only method of practical use. Cultures and animal inoculations presuppose so much time that these procedures are adaptable only to chronic cases and to the tuberculous form of meningitis.

One seeks bacilli on the fibrinous threads which form in the tube after standing or after centrifugation of the fluid.

In the so-called microbial forms of meningitis many kinds of bacteria have been found, the staphylococcus (*Josias, Netter, Stadelman,* etc.), the streptococcus, *Fraenkel's* and *Weichselbaum's* pneumococcus, the *Ebert* bacillus (demonstrated by *Wentworth* and *Lenhartz*), the colon bacillus, the tubercle bacillus, and many others.

The tubercle bacillus, especially, has caused great trouble and raised much discussion. It is not found in all cases, and the variable results are explained by the different methods employed by the respective workers. *Kroenig* (64) attributes failure to an imperfect centrifugation, or to a poor stain; he states his belief as to the possibility of demonstrating tubercle bacilli in each and every case of tuberculous meningitis (65).

Schwartze (66) endorses *Furbringer's* method of spontaneous clot production after permitting the fluid to stand twenty-four hours as preferable to centrifugation of the fluid; he divided the fluid into two parts, one of which was subjected to centrifugation and demonstrated the bacilli only in the untreated portion.

The absence of tubercle bacilli may be due to the fact that the meningeal tubercles have not broken down, or that they are limited to the cranial meninges and the communication between the two cavities is clogged or obliterated, or that the puncture has penetrated into the subdural space. (*Stadelman* 67.) This

opinion is plausible for certain cases, but less satisfactory than the explanation of negative findings by reason of faulty technique.

When found the tubercle bacilli are always present in small numbers, a warning that not every rod retaining the stain after the *Ziehl* solution and sulphuric acid discoloration should be considered as *Koch's* tubercle bacilli is sounded by *Griffon* and *Philbert.*

As to the culture methods, the advantages of conclusive results are offset by the delay in the appearance of the culture growths, usually two or three weeks. This prevents the practical application of culture methods for diagnostic purposes in the majority of the intracranial complications of middle ear disease.

Negative results do not by any means demonstrate the absence of micro-organisms in the cerebrospinal fluid. The cultures may prove failures because the medullary canal did not share in the inflammatory process, or because the fluid itself had bactericidal properties preventing the preservation of bacterial vitality or virulence, or because these bacteria have become independently attenuated (*Leutert*). The pneumococcus and the meningococcus are feebly virulent in the purulent exudate of meningeal inflammation, and they yield no culture for from eight to ten days after the onset of the disease. (*Concetti* 24.)

Besancon and *Griffon* obtained a positive result in regard to the tubercle bacillus by adding a few drops of the fluid to gelatinized blood. Twelve to fifteen days later the colonies were visible to the naked eye.

Animal inoculation is of especial value for the demonstration of tubercle bacilli, but the method demands at least three weeks' time. The fluid is introduced into the peritoneum of guinea-pigs; the results may be negative for similar reasons as in the case of the cultures, generally on account of the diminished virulence or the small numbers contained in the inoculated fluid.

Inoculation was successful in 27% of the cases of tuberculous meningitis of *Bernheim* and *Mosser*, and in 30% of those of *Netter.* The scientific accuracy of these examinations is incontestable according to *Variot* (68). Their value is, however, only

relative for the clinician who requires prompt information. The answer from the laboratory comes of necessity so late that in the case of tuberculous meningitis the paralytic phenomena of the final stage will precede and confirm them (*Chavasse* and *Mahu*).

4. *Cytodiagnosis.* This method of examination, recently introduced by *Sicard, Widal,* and *Ravaud,* 1900, consists as already indicated, in the histological study of the cellular elements contained in the spinal fluid, this study being based on the determination of the number and nature of its formed elements. Remarkable practical results have been obtained by this method, which *Wentworth* (84) had suggested in 1896 and *Bernheim* and *Mosser* (85) in 1897, for the study of meningeal affections.

By means of cytodiagnosis as a routine measure certain cytological formulæ have become established in connection with various cerebral or cerebrospinal affections.

Normal cerebrospinal fluid or fluid unaltered by general or nervous diseases contains only a few leucocytes, not more than one or two in the microscopic field. When, on the other hand, the meninges are the seat of irritation or inflammation, formed elements appear in the fluid whose number and character vary with the intensity and nature of the inflammatory process, representing at once a qualitative and quantitative reaction.

The technique of the method is described in detail in the works of *Widal, Sicard,* and *Ravaud,* and is of easy and practical applicability. The succeeding microscopic examination must be made with the greatest care and thoroughness, since the leucocytes may be unevenly distributed—being occasionally much more numerous on some slides than on others. The observer must be able to recognize, differentiate, and count the different elements. (*Sicard* (86).)

The lymphocytosis of the cerebrospinal fluid indicates only the presence of meningeal irritation, and therefore does not in itself furnish information as to the nature of the irritating process. Being simply a sign of meningeal irritation, it does not invariably indicate meningitis. *Dana* (151) found increased lymphocytosis present in two cases of paresis, while in two other cases the fluid was clear.

Lymphocytosis of the spinal fluid is especially observed in chronic meningeal affections, as for instance in tabes (91), multiple sclerosis, syphilis, and tuberculous meningitis.

Polynucleosis is the sign of an acute and violent irritation. It is usually found in acute nontuberculous meningitis from various causes (pneumococcus, staphylococcus, meningococcus). At this stage the fluid contains almost solely polynuclear leucocytes, generally in sufficient numbers to give the fluid a cloudy aspect. Sometimes the fluid appears normal and the polynuclear leucocytes are only discoverable after centrifugation. It has been noted of the fluid, especially in cerebrospinal menignitis, that the polynuclear leucocytes decrease as recovery progresses, then they are replaced by lymphocytes, which in their turn gradually disappear when recovery is complete. (*Labbi* and *Castaignes*, *Sicard* and *Bricy*.)

In a case (155) of otitic purulent meningitis recently under observation, the decrease in polynuclear leucocytes and the increase in the number of lymphocytes advanced proportionately as recovery progressed.

Polynucleosis has been occasionally observed in tuberculous meningitis. According to *Braunstein* it is often found in suppurative meningitis complicating middle-ear disease. *Leutert* states as a result of his work on the complications of middle-ear disease that a marked general leucocytosis usually strongly suggests meningitis, an opinion shared to some extent by *Lenhartz*. Polynuclear leucocytosis, as always suggestive of meningeal inflammation, had previously been commented on by *Stadelman*, *Bernheim*, *Mosser*, *Lichtheim*, and *Wentworth*.

5. *Chemical Examination.* For purposes of diagnosis the chemical character of the cerebrospinal fluid is indifferent and devoid of practical value in ordinary cases. The normal reaction is alkaline, presenting a considerable proportion of sodium chloride, and containing neither fibrinogen nor fibrin ferment. In meningeal inflammations the albumin increases, especially in the suppurative forms where it may reach 7% or even 9%. In such cases, however, the diagnosis can be made by the gross aspect of the fluid. *Daskiewitz-Korybut* believes that a percentage of more than 1% in the albumin points to inflam-

matory processes and should be taken as a contraindication of tumor.

Reiken (83) holds that in tuberculous meningitis the average of albumin is about 2%.

Fuchs (152) believes that there is still much room for improvement in the technique of the physical and chemical methods of examining the spinal fluid. He attaches great importance to the determination of the freezing point and to the electrical conductivity of the fluid.

The constant raising of the freezing point in all forms of meningitis, and the disturbances in the relative values of the electrical conductivity and the freezing point he interprets as an alteration in the relative proportions of organic and inorganic constituents, which he believes occurs in meningitis exclusively.

6. *Cryoscopy.* The determination by cryoscopy of the osmotic tension of the cerebrospinal fluid means the establishment of its coagulation point as compared to that of blood serum, and has been employed by *Sicard, Widal,* and *Ravaud* (87). This procedure necessitates special instruments, and *Bard* prefers hematolysis according to the *Hamburger* method of determination of the isotonicity of saline solutions. This procedure consists in trying if the cerebrospinal fluid is stained by the influence of a few drops of blood added to the puncture fluid, which is then subjected to centrifugation. In the normal state the cerebrospinal fluid does not "leak," but "leakage" occurs when it is in a state of hypotonia. *Bard* (88), however, admits the inferior value of hematolysis as compared to cytology in the diagnosis of acute forms of meningitis, since it does not assist materially in the differential diagnosis, presenting "leakage" in tuberculous meningitis, and even in slight inflammatory conditions and meningeal implications due to profound intoxication.

Interesting as they are from the scientific view exclusively, the results of cryoscopy and hematolysis up to the present writing are possessed of almost no practical value.

Summing up these various methods of examination of the spinal fluid, it should be borne in mind that it is not so much a given characteristic of the cerebrospinal fluid, but the totality of its examination which should furnish diagnostic indications, and

the results of this examination should always be considered in connection with the clinical development of the case. Erroneous conclusions are only too easily arrived at in the difficult cases where lumbar puncture is undertaken in order to assist an uncertain or a doubtful diagnosis.

Significance of Pathological Findings: During the first period of intercranial complications of middle-ear disease, at a time when judicious interference may serve to rescue the patient's life, diagnosis frequently presents enormous and even insurmountable difficulties. The importance of the specialist's decision in these serious cases is such that he is called upon to resort to all the exploratory methods furnished him by general medicine for the solution of his complicated problem.

The presence of otitis media does not by any means exclude the possibility of a cerebrospinal meningitis or a tuberculous meningitis, both entirely independent of the ear disease proper. The existence of a chronic tuberculous otorrhœa creates an equal predisposition for the development of a tuberculous meningitis, as it does for that of a simple purulent meningitis from infection by contiguity.

The choice between the two may occasionally prove most embarrassing. (*Luc* (70).)

Stadelman (71) stated ten years ago that the differential schedule to distinguish purulent meningitis, tuberculous meningitis, and brain abscess was as follows: A clear fluid with tubercle bacilli indicates tuberculous meningitis. A turbid liquid, clouded up to purulency with various forms of micro-organisms, means suppurative meningitis, and a clear liquid without micro-organisms points to brain abscess.

This summary, although not infallible, represents considerable progress in the diagnosis of intracranial complications of ear disease. But the advance that has since that time been made in the methods of examination of the cerebrospinal fluid, coupled with a wider knowledge of ear complications, permits of a new and generally applicable—although not yet perfect—schedule fitting the majority of cases. According to *Chavasse* and *Mahu* (72) a clear, normal noncoagulable fluid indicates sinus thrombosis, brain abscess (epi- or subdural), simple serous meningitis,

meningismus, hysteria, and occasionally a circumscribed meningitis. If the fluid comes away in spurts under pressure the probability of serous meningitis, sinus thrombosis, or more rarely brain abscess, is increased. A clear fluid without bacteria or coagulating elements makes for a probable diagnosis of meningitis, toxic (?) or tuberculous. A clear or yellow or slightly turbid fluid with predominating lymphocytosis, or the tubercle bacilli, indicates tuberculous meningitis after clinical elimination of other causes of lymphocytosis, if there are no tubercle bacilli present. An opalescent or purulent fluid, forming a coagulum, with predominating polynucleosis, and eventual presence of various micro-organisms, means acute diffuse meningitis, purulent or nonpurulent, cerebrospinal meningitis (provided *Weichselbaum's* meningococcus is present), and if the puncture is hurried—*i.e.*, the fluid aspirated—sometimes it indicates a circumscribed meningitis.

Apart from the clinical symptoms, lumbar puncture does not give the mathematical certainty of establishing the differential diagnosis between brain abscess, serous meningitis, meningismus, or sinus thrombosis. It is thus shown that lumbar puncture fails precisely for the differential diagnoses of greatest importance to the otologists, leaving doubt also as to the existence of a circumscribed meningitis.

The opinions of observers who have made a special study of lumbar puncture vary widely as to the practical value of *positive* results of the examination of the spinal fluid—meaning a change in the constituency of the fluid—and of *negative* findings—meaning a normally constituted fluid.

Stadelman, in 1895, considered negative results as devoid of value, especially for differential diagnosis between brain abcess and purulent meningitis. Since that time he has modified his opinion. *Braun* (73) admits only positive findings for the diagnostication of meningitis, and *Lichtheim* (74) reports a case diagnosed as diffuse meningitis because the fluid was cloudy from the presence of leucocytes, but which turned out to be a circumscribed meningitis.

Leutert (75) and also *Cheney* (82) attach importance to a negative finding, the object of the former being especially to exclude

meningitis. He takes a quantity sufficient in amount (12 to 15 cm.) to ascertain the withdrawal of the fluid from the cranial cavity.

Chavasse and *Mahu* consider this last condition as superfluous, as demonstrated by recent application of the cytodiagnostic method the cerebrospinal fluid is not a stagnating, stationary liquid, there being a constant interchange between the cranial and the spinal cavities.

According to *Leutert*, an objection to placing too much value on negative findings is the possibility of an existing obstruction of the communication between these two cavities. This obstruction is demonstrated when it is possible to withdraw only a very small quantity of the fluid.

Grünert (76) agrees with *Leutert* in trying to exclude diffuse purulent meningitis by lumbar puncture. He lays great stress on the data derived from the clinical picture.

Braunstein summarizes the conclusions of *Leutert* and *Schwartz* laid down at the "Versammelung Deutsche Naturfoerscher und Aerzte zu Hamburg, 1901," as follows: A negative result, fluid clear and normal, definitely excludes the existence of diffuse purulent meningitis. A positive result, fluid turbid from increase of leucocytes, with presence or absence of micro-organisms, demonstrates the existence of diffuse purulent meningitis, or of cerebrospinal meningitis (if the meningococcus intracellularis is present). *Braunstein* does not consider it essential that the leucocytes present must be polynuclear, but he admits that the fluid may show turbidity in case of brain abscess.

At a time when the cytodiagnostic method was not yet in use *Luc* wrote that in a doubtful diagnosis between encephalic abscess and meningitis the absence of microbes in the fluid withdrawn by puncture and the innocuity of the fluid when inoculated into laboratory animals presented strong presumptive evidence in favor of brain abscess.

Körner (77) considers lumbar puncture as a frequent but not invariable positive diagnostic measure in otitic leptomeningitis. He makes the reservation that a fluid slightly cloudy with bacteria may be found in diffuse as well as in circumscribed menin-

gitis, and that there may be circumscribed meningitis with a clear fluid.

Schultz (78) declares that neither the macroscopic aspect of the trouble nor the microscopic evidence of increase of leucocytes are in all cases sufficient for the establishment of the diagnosis of diffuse purulent meningitis; he, however, attributes great importance to the bacteriological examination which, as we have already seen, unfortunately are often a failure, as are also the attempts at making cultures.

Cytology as applied to general medicine furnishes some points of interest for the study of the otitic forms of meningitis. *Netter* (92) does not consider a clear fluid a conclusive proof of the absence of meningitis; moreover, the aspect of the fluid may vary with the time of the puncture. *Archard* and *Laubry* (79) believe that if positive results of lumbar puncture are taken to indicate the presence of meningitis, a negative result should not be held as irrefutable proof that no meningitis is present. For *Sicard*, the withdrawal of a clear fluid without leucocytes suffices, given the presence of doubtful meningeal symptoms to determine the absence of a meningeal inflammation.

Differential Diagnosis: In children especially tuberculous meningitis and cerebral tubercles are often observed, either as a complication of tuberculous otitis or as an accompanying result of non-tuberculous ear disease; moreover, tuberculous meningitis is often incorrectly diagnosed as ordinary meningitis or even as brain abscess. In order to prevent an eventual useless operation the examination of the cerebrospinal fluid is resorted to as a diagnostic aid.

The fluid obtained in these cases is generally clear and transparent, sometimes greenish yellow or tinged with blood.

Wentworth claims that, when compared to distilled water, the fluid is almost invariably cloudy. It flows out under pressure, and the coagulum which forms in it is muddy, white, or gray, quite hard, and not easily smeared on slides (*Netter*). The tubercle bacillus is demonstrable microscopically in about an average of 50% of all cases, always in small numbers. Not so long ago the demonstration of the tubercle bacillus meant the crucial test for the presence of tuberculous meningitis, and as this examina-

tion was frequently negative, *Monti* (100) held that lumbar puncture was devoid of value as an aid to diagnosis. *Friedjung* (101) held similar opinions. But the significance of the examinations has been materially changed by the work of *Widal, Sicard,* and *Ravaud,* as already described. Cytodiagnosis invariably shows an excess of lymphocytes, sometimes mixed with polynuclear leucocytes and endothelial cells.

In some cases this lymphocytosis seems to have led to a diagnosis of tuberculous meningitis when there was present only a simple meningitis, as demonstrated at autopsy.

Diffuse purulent meningitis due to various microbes is the most commonly observed form of this disorder as a complication of suppurative middle-ear disease. In diffuse suppurative leptomeningitis arising as a complication of ear trouble, or accompanying sinus thrombosis or brain abscess, the fluid withdrawn by puncture is changed both macroscopically and microscopically. The seat of the suppurative process is commonly the subarachnoidal (exceptionally the subdural) space. The fluid is accordingly seen to be cloudy, greenish yellow, sometimes typically purulent, very frequently containing various forms of microbes, such as the staphylococcus, the streptococcus, the pneumococcus, etc., and considerable quantities of leucocytes. The pressure varies from high (*Stadelman*) to low (*Chavasse* and *Mahu*). Cytodiagnosis confirms the typical increase of polynuclear leucocytes in suppurative meningitis, especially of the otitic form. (*Leutert* (102).) *Braunstein* believes that the presence of bacteria is not essential for the diagnosis of meningitis, but that a hyperleucocytosis with a turbid fluid points directly to the existence of a purulent meningeal inflammation. In a case of suppurative meningitis observed by *Chavasse* and *Mahu* the puncture fluid contained many polynuclear leucocytes and some pneumococci. In another case, one of multiple brain abscess, the fluid was slightly opalescent and cytodiagnosis demonstrated the presence of many polynuclear leucocytes. In a case of suppurative cerebrospinal meningitis following posterosuperior mastoid cellulitis, the fluid obtained by puncture was found to be cloudy and to contain pneumococci (103).

Lumbar puncture performed on a patient suffering from men-

ingitis developing a month after mastoid abscess, yielded 4 to 5 c.c. of fluid in which cytodiagnosis demonstrated the presence of formed elements, while bacterial cultures proved negative. In the majority of cases of purulent meningitis of otitic origin *Chavasse* and *Mahu* claim that the diagnosis is facilitated by the determination, first, of a cloudy fluid, and second, a cloudy fluid with predominant polynuclear leucocytes. In one of the cases observed by *Lichtheim* the fluid was not cloudy, notwithstanding an extensive basal meningitis; in another the fluid was cloudy, but did not contain any polynuclear leucocytes.

Turbid fluid without bacteria or hyperleucocytosis is mentioned by *Heinike* (104) as occurring in one of his cases.

Lumbar puncture practiced on a child with chronic mastoiditis, complicated with a disease whose clinical picture was that of leptomeningitis, yielded a clear fluid under moderate pressure in which the microscopic examination after centrifugation showed neither corpuscles nor micro-organisms. Agar cultures remained sterile. Autopsy, however, demonstrated suppurative leptomeningitis with a turbid fluid in the ventricles. (*Witte* and *Sturm* (105).)

Grossmann (106) had results from puncture in one case which would have led him to the diagnosis of diffuse meningitis, but notwithstanding his findings, he operated upon the case and the symptom-complex cleared up entirely; in another, a case of general otitic sepsis, the fluid was cloudy and contained pus elements, but upon autopsy no meningitis was demonstrable. This last case is hardly one from which to draw inferences as to the diagnostic value of the puncture method, as I believe that when a general sepsis supervenes, whether it comes as a complication of middle-ear disease or after surgical measures, if advanced to any extent, all the fluids of the body will give evidence of pus elements.

Cohen (107) insists that the fluid is almost always abnormal in suppurative meningitis provided the puncture is not undertaken too early in the course of the disease.

Obliteration of the connecting passage between the spinal and the cranial cavities is assumed as an explanation of the normal fluid withdrawn by puncture in a case of meningitis, which

diagnosis was confirmed by autopsy by *Archard* and *Laubry* (108).

In cases of posterior-basic meningitis among children, *Koplik* (154) does not always find the puncture successful in evacuating fluid. Occasionally he secured dry taps because of the closure of the foramen of *Magendie* by exudate and because of the matting together of the spinal canal in the vicinity of the cerebellum and pons. This latter finding occurred to such an extent that it prevented the flow of the subarachnoid fluid from the subarachnoidal space and ventricle of the brain into the space of the cord. He finds the puncture of only negative value as far as diagnosis was concerned in cases of hydrocephalus following posterior basic meningitis. He obtained only a sterile fluid. Of six cases of posterior-basic meningitis, younger than two years of age, one gave a negative result from puncture; another, although presenting a typical clinical picture, gave but little fluid upon puncture, which was found to be sterile; a third gave the meningococcus; the fourth gave the meningococcus upon the second puncture; the fifth case gave meningococcus, and the sixth case, which developed hydrocephalus while under observation, gave as much as 250 c.c. of fluid at one puncture without micro-organisms.

Koplik reports the fluid as being cytologically similar to that found in tubercular meningitis. The fluid contained mononuclear leucocytes. Such a finding, according to this observer, is characteristic of chronic cerebrospinal meningitis.

Regarding *Koplik's* findings, the puncture fluid in the majority of his cases, gave the polynuclear picture in addition to micro-organisms.

Strauss (109) also accounts for these peculiar observations by the occlusion of the foramen of *Magendie* by the inflammatory exudate.

In cerebral or cerebellar abscess uncomplicated by other affections, intercranial in their nature, or by sinus thrombosis, diffuse or circumscribed meningitis, the fluid is, as a rule, normally clear, without organisms, and yielding no coagulum. After centrifugation *Lermoyez* (110) found the clear fluid to be normal. The quantity of the fluid may be altered by the existence

of sinus thrombosis, but it generally remains clear. (*Laurens* (111).)

Constade (112) noticed a dripping evacuation, drop by drop, of a clear fluid from a child eleven years of age who died of lateral sinus thrombosis confirmed by autopsy.

A circumscribed suppurative meningitis may present the same symptoms as the diffuse form of the disease, and here lumbar puncture is quite apt to yield a normal negative fluid. Where there are symptoms of circumscribed otitic meningitis *Grünert* (113) points out the eventual existence of a circumscribed otitic meningitis proper. According to *Hinsberg* (114) a clear and sterile fluid does not absolutely contraindicate a circumscribed inflammatory focus. *Koerner* (115) believes that a slightly turbid fluid with bacteria may be found as well in diffuse as in circumscribed meningitis, and that there may be circumscribed meningitis with a clear fluid without pus elements or micro-organisms.

Lannois and *Armand* (116) report a case of cerebellar abscess by extension from a suppurating labyrinth, complicated by a localized meningitis, in which they withdrew by puncture thirty to forty grams of slightly turbid fluid which, after centrifugation, showed many polynuclear leucocytes with indistinct and faintly stained nuclei, and a few mononuclear leucocytes but no lymphocytes.

In pachymeningitis, intradural abscess, and extradural suppurations the fluid may retain its normal composition; thus, *Braunstein* made several observations concerning extradural lesions, even when complicated with cerebellar abscess, in which the puncture yielded a clear and normal fluid, and *Laurens* (117) withdrew transparent fluid from a case of extradural abscess with pachymeningitis of otitic origin. On the other hand, *Berstelmann* (118) obtained cloudy fluid with deposits of many leucocytes and a few fine specimens of the diplococcus intracellularis from a case of extradural abscess which terminated in recovery after surgical interference. The composition of the fluid may eventually be accounted for by the existence of a slight cerebrospinal meningitis.

In cases of intradural abscess lumbar puncture may yield a

clear fluid without leucocytes or micro-organisms or formed elements, as shown by cytodiagnosis (*Leutert*).

Bacteriological and cytological examinations have not given much information on the subject of the various forms of serous meningitis, as observed with special frequency in infancy and childhood and so frequently confounded with cerebral abscess (*Broca* and *Laurens* (119), *Leyden* (120), *Hegener* (121), and *Boenninghaus* (122).)

Of the various forms of ear disease the simple mastoid affections are the only ones which do not cause a modification of the cerebrospinal fluid. This should be kept in mind because of the existence of certain morbid conditions simulating or complicating this ear disease.

I cannot complete the study of the diagnostic possibilities - lumbar puncture without touching upon a series of symptoms to which the name "meningismus" has been applied.

There are a series of symptoms occasionally observed in the course of suppurative middle-ear disease, especially in children, but occasionally in adults, which simulate either simple or tuberculous meningitis and brain abscess. In these cases no inflammatory lesion is supposed to exist, and to this symptom-complex the term "meningismus" is restricted. It does not include the serous forms of meningitis. (*Dupre* (123), *Gelle, Massin, Chavasse* (124).)

For the development of meningismus, hysteria and neurasthenia have been held accountable, and *Lermoyez* has attributed it to reflex symptoms from a suppurative inflammation of the labyrinth. *Dopter* (125) has observed meningismus in cases of typhoid fever.

In true meningismus, which is simply the manifestation of functional trouble without implication of the serous membranes, the cerebrospinal fluid is normal, according to *Widal* and *Lamouroux* (126).

In two cases of labyrinthine disease, both females, in whom no hysterical elements were demonstrable, the fluid withdrawn by puncture flowed without heightened tension, was clear and contained no formed elements (*Chavasse* and *Mahu*).

In ear disease, acute non-tuberculous meningeal inflammations

are of frequent occurrence, and according to *Netter* (127) the milder and non-purulent forms may retrocede rapidly without leaving traces behind them. In these cases lumbar puncture will yield a clear and apparently normal fluid, which after standing some hours presents scanty flakes of fibrin and may contain albumin and some pneumococci.

Merkens, *Brieger*, and *Koerner* admit the possible occurrence of a serous meningitis due to a penetration of toxins from a suppurative otitic focus to the meninges. The toxin of the pneumococcus circulating in the blood has been held responsible for the development of the condition by *Belfanti* and *Hutinal* (128).

Cerebrospinal fluid then is seen to be normal in composition in labyrinthine disease and in meningismus, while in brain abscess, lateral sinus thrombosis, and non-bacterial serous meningitis it may be clear and normal, but it is often increased in amount and generally flows under heightened pressure.

The conflicting observations obtained from diffuse meningitis may in a measure be accounted for by the fact that in certain of their cases the differential diagnosis between diffuse, simple, tuberculous, and non-tuberculous meningitis and meningismus had not been made, especially the differential diagnosis between diffuse meningitis and the condition known as meningismus. Reading certain results obtained by puncture one is inclined to believe that the observer was dealing with meningismus rather than with a meningitis proper. Taking those cases where there was present a clear and normal fluid, and in which the diagnosis was not confirmed by autopsy, and classifying them under the heading "meningismus," the diagnostic data reads clear and distinct.

In summing up the diagnostic possibilities of lumbar puncture we are inclined to believe it a measure of great value, especially when undertaken rather to clear up doubtful diagnoses than to substantiate probable ones. The data obtained should invariably be considered with the clinical evidence of the disease, and where the question involved is one as to whether or not surgical interference should be undertaken, it is well to give the patient the benefit of the doubt.

II. As a Therapeutic Measure: In 1891 *Quincke* (1), after extensive experimentation on dogs and rabbits, performed the first original operation of lumbar puncture on a patient—a child two years old—for the purpose of relieving a fresh hydrocephalic effusion, with pressure symptoms, by means of withdrawing cerebrospinal fluid. The puncture was repeated three times at intervals of several days, resulting in an almost complete recovery of the patient.

The lucky outcome of his brilliant venture encouraged the surgeon to further experimentation, and he published his results in an article on the physiological and pathological conditions of pressure on the cerebrospinal space, as well as the physical and chemical constitution of the fluid withdrawn by puncture, in various conditions of the disease (2). It was not long before *Quincke* had performed the operation twenty-two times on ten individuals (3).

While *Quincke* had had a fair proportion of therapeutic success, *Lichtheim* (4), working at Koenigsberg, reported on a series of spinal punctures performed by him without relief to the patients. Even very pronounced symptoms, in cases of brain tumor, were not even transitionally relieved by the withdrawal of very large amounts of cerebrospinal fluid (80 cm.). Notwithstanding these negative results *Lichtheim* believed that lumbar puncture possessed diagnostic value.

The experience of *Ziemssen* (5) with *Quincke's* puncture was favorable in so far as he observed improvement of pressure symptoms after the operation, especially finding relief from oppressive headaches. He pointed out the advantage of utilizing the cerebrospinal fluid thus obtained for admixture with medical agents.

Wyss (6) reported a case of hydrocephalus in a child eight months old improved by six ventricular and one lumbar puncture, and *Dennig* (7) obtained post-mortem a large quantity of tubercle bacilli by means of spinal puncture from a case of tuberculous meningitis.

The finding of tubercle bacilli has frequently been duplicated, notably in the remarkable case of tuberculous meningitis ending in recovery reported by *Freyhan* (8).

After 1895 professional interest became more general, and the subject of lumbar puncture came up for discussion at various congresses and lectures (9).

While *Ziemssen* pointed out the advantage of mixing the cerebrospinal fluid with medical agents in 1893, the first observer to replace the spinal fluid by a medicated one or a serum was *Chipault* (10), 1897, although cocaine had been introduced into the spinal canal (cauda equina) by *Leonard Corning* (11), an American neurologist, ten years before *Bier*, the German physician, to whom the claim for priority for "medullary anæsthesia" is generally conceded.

Broadly speaking, lumbar puncture affords two ways of therapeutically influencing a given lesion:

1. By affording a road for the introduction of medicaments into the spinal canal, and from there to the cranial cavity, with the idea of producing a resultant action directly upon the cranial or spinal lesion.

2. As a means of producing favorable therapeutic action by withdrawal of excessive amounts of fluid, thus relieving pressure, and also simultaneously with the withdrawal of the fluid, bringing about the removal of causative foci of disease.

In the application of the first-named principle of lumbar therapeutics many drugs have been employed. Sterilized air (*Weill*), sodium salicylate (*Caille*), potassium iodide, iodoform, and antitetanus serum are some of many which have been found of use by various observers. The idea of a direct action on the meningeal lesion has not been generally successful from the practical standpoint; the greatest success has attended the introduction of the antitetanus serum, and at that this is by no means universally favorable. In tuberculous lesions the idea was particularly popular, but the therapeutic success doubtful.

The second therapeutic principle, the idea of producing a favorable therapeutic result from the withdrawal of spinal fluid, has brought forth wide divergence of opinion. We will study some of these opinions in detail.

The therapeutic value of lumbar puncture in meningitis has the endorsement and recommendation of many able observers; thus *Quincke* (12) finds it useful in cases of serous and sero-

purulent meningitis, a result which *Goldscheider* (112) and *Oppenheimer* (38) confirm from their own experience.

Its good effects in this condition are due to the relief of intercranial pressure. (*Osmond Goldan* (13).) On the other hand, *Stockton* (14) and *Browning* (15) are not so positive in their claim for it in these forms of meningitis; they believe it of therapeutic value provided the first puncture gives good results, then they recommend its frequent repetition.

Kohts (16) reports lumbar puncture as having positive curative virtues in suppurative cerebrospinal meningitis, while *Donath* (17) only points out its sedative action in this condition.

In serous meningitis secondary to the exanthemata in children *Wertheimer* (19) reports most favorably on its therapeutic virtue. *Friedrich* (139), in his recently published book, discusses the forms of operative interference in purulent meningitis inclusive of the method of repeated lumbar puncture, followed by injection of physiological salt solution for the evacuation of pus from the spinal canal. He, however, makes a counter-opening into the cranial cavity to secure free evacuation of the purulent exudate.

The use of lumbar puncture in tuberculous meningitis has many adherents. It seems to have a sedative and analgesic effect, relieving the somnolence, and for a time even the coma (*Kohts*), while its action in relieving the intensity of the pain has also received favorable notice. *Marfan* (18) would limit its application to those cases of tuberculous meningitis where pressure symptoms develop along with incipient coma and hyperpyrexia, accompanied by loss of sensation, muscular flaccidity, and pupillary dilatation. *Marian* (20) unqualifiedly recommends its use in tuberculous meningitis.

An uncertainty of opinion exists among these various observers as to the relief which the measure affords to hyperdistention of the cerebrospinal fluid in this form of meningitis.

Francis Huber (21) is of the opinion that the therapeutic effect of lumbar puncture is a great one, and he uses it as a therapeutic measure in otitic serous meningitis, the cerebrospinal type of typhoid, and also in cerebrospinal meningitis.

In addition to the relief of pressure symptoms lumbar puncture

serves to evacuate with the spinal fluid the larger part of the agents of suppuration, microbic and toxic, which have penetrated into the subarachnoidal space. It induces the secretion of a new cerebrospinal fluid which may be stronger in active bactericidal powers. (*Brieger* (133), *Pillagot* (134), and *Hand* (135).)

Originally designed by *Quincke* for the relief of hydrocephalic effusions, many observers have since confirmed his early results. *Marian* (20), *Bokey* (22), *Pfandler* (23), *Kohts* (16), and others have reported favorably in regard to its therapeutic value in cases of hydrocephalus, *Marian*, especially, holding the belief that its practice conduces to spontaneous recovery of the patient. According to these authors its results have been theoretically accounted for and practically demonstrated (*Pfandler*).

The procedure has been recommended to the general practitioner, especially to those interested in pediatrics. In hydrocephalus, complicated by spina bifida, *Kohts* obtained good results; *Bokey* reports its curative effect in hydrocephalus secondary to meningitis. In one case of chronic hydrocephalus all the symptoms disappeared after eight months, during which time eleven punctures had been made, withdrawing in all about 283 cm. of the fluid. A second case, although dying from an intercurrent disease, was much improved. *Concetti* (24) finds a palliative action the only one to be expected in chronic hydrocephalus.

Gradually the boundaries of the therapeutic indications for lumbar puncture were widened, and we find it recommended for the alleviation of the pains of chronic neuralgia secondary to zona by *Abadie* (25), who obtained excellent results in three cases of neuralgia accompanying humoral zona and zoster. He found that the evacuation of 19 to 20 cm. of fluid served to relieve the pain. According to him the curative effect is to be sought for in the return of the pressure—spinal and intracranial—to the normal after hypertension because of the cerebrospinal fluid.

In headaches secondary to syphilis *Campbell* (26) found the puncture of excellent use. While *Pfandler* holds that the relief of symptomatic headache justifies its employment in this condition, the headaches of chlorosis are said to be almost immediately

relieved by the abstraction of 30 to 60 cm. of spinal fluid. (*Wertheimer* (19).) *Lenhartz* (28) reports eight such cases, seven improved.

On the other hand, *Milan* (27) brings contra-evidence of its success in syphilitic headache. He used the puncture in a case of a young woman and withdrew only 6 to 7 cm. of fluid, yet the symptoms were aggravated to an excruciating degree, and there developed nausea with uncontrollable vomiting and accompanied by a thready pulse, leading to the classical picture of fatal syncope. This symptom-complex cleared up within a week.

The headaches of *Bright's* disease were treated and improved by means of lumbar puncture by *Pierre Marie* and *George Guillian* (131). Furthermore, *Schert* states that the procedure brought instantaneous, though only temporary, relief with diminution of the œdema, and a clearing of consciousness in a case of uræmia. *Sieffert* (31) also reported favorably on the effect produced by the puncture in cases of uræmia following scarlatinal nephritis. He believes the procedure a valuable adjunct to other therapeutic measures in this condition. *Legendre* (137) is also among those who had successful therapeutic results in uræmia, while *Legrain* and *Guyard* (138) always obtained relief from headache and secured sleep by means of the puncture repeated at intervals of from a fortnight to a month in a patient aged fifty-six years suffering from chronic nephritis.

Among those inclined to place a therapeutic value on the puncture in cases of uræmia are *Quincke, Furbringer, Lichtheim,* and *von Leyden* (120).

Finally, the headaches of chronic saturnine intoxication of the nervous system have been relieved and cured by means of the puncture at the hands of *Seegelken* (153).

In affording relief to the lightning pains of tabes, especially during gastric crises with painful vomiting, *Donath* (29) was successful. *Joseph Fraenkel* used it successfully in seven such cases. He also found the puncture useful in diminishing the frequency and violence of epileptic attacks. *Koranyi* (30), however, only expects palliative results in epilepsy; he does not expect a cure.

Good results from lumbar puncture have also been observed in

Huntington's chorea, cerebral venous hyperæmia, and spastic torticollis (*Donath*).

Nor are these all the conditions where the puncture has been found of therapeutic value. In the treatment of meningeal œdema following traumatism it has proved useful (*Lenhartz*), and in cases of hemorrhage in the cord, the spinal punctures in the hands of *Strauss* (32) again demonstrated its usefulness. This author would restrict spinal puncture to those cases which occur in previously healthy persons where the hemorrhage resulted from traumatism.

Goldscheider (33) had favorable results from the puncture in two cases of small brain tumor situated at the base of the brain. Similar good results in this condition are reported by *Kohts* (two cases), while *Masing* (39) cautions against the employment of the puncture in cases of brain tumor, and relates the following case in point from his experience: The patient's condition was diagnosticated as a brain tumor, and the puncture was undertaken and 30 cm. of fluid withdrawn. During the operation there was nausea, later restlessness and vomiting, and finally death followed in fifteen hours after the operation. Autopsy showed extensive recent hemorrhage in the right temporal lobe, the wall being formed by a gliosarcoma (demonstrated per microscope) with central softening.

Of interest to otologists are the reports on the value of lumbar puncture in the management of dry otitis media, with its accompanying tinnitus; thus we find that *Luminean* (34) abstracted small amounts of spinal fluid, a procedure which he characterized as perfectly safe, to obtain relief in cases of cicatricial otitis—the dry form of otitis. He obtained relief from the annoying tinnitus and vertigo of labyrinthitis and its complications. His results were generally good. He even goes so far as to claim a "cure" for the tinnitus. *Mignon* (35), on the other hand, claims to have observed an effect only in cases suffering from labyrinth troubles, secondary to an excess of pressure in the fluid of the internal ear. He obtained relief and cure of the vertigo and tinnitus in four cases under his observation. Occasionally he was able to observe a slight improvement in the hearing power, which he believes due more to the timely interference than to any other

cause. On the other hand, *Lombard* and *Caboche* (36) have not had a single case of absolute cure among seven cases of dry otitis media with tympanic adhesions accompanied by deafness, tinnitus, and vertigo. The latter symptom was the one most favorably influenced by lumbar puncture. The last-named authors claim to have failed to establish any relationship between the improvement noted and the intraspinal pressure at the time of puncture. They noted the most favorable results in those cases where the patient presented marked vasomotor symptoms of the head and face.

Babinski (37) recommends rachicentesis as a therapeutic measure in the management of ear affections, more especially in auricular vertigo. He advocates the systematic adoption of lumbar puncture in the management of all chronic ear cases. Certainly, his remarkable curative results in treatment of ear affections—deafness, tinnitus, and auricular vertigo—merit the very serious attention of ear surgeons to this modern method, the effect of which he has demonstrated as infinitely superior to all and everything tried so far for the relief of dry, chronic, middle ear disease. He treated eight cases with excellent results. In several cases the psychic condition brought about by the ear disease improved at the same time. The power of hearing was very favorably influenced in a few instances, the good effects remaining fairly permanent, in one case over three months and a half at the time of the report (130).

The rachicentesis recommended by *Babinski* in the management of ear affections, more especially of auricular vertigo, was tried by *Tretrop* with fortunate results in the treatment of deafness due to labyrinth trouble alone or complicated with other lesions of the hearing apparatus. The vertigo was the symptom most favorably influenced, next the tinnitus, and finally the deafness.

Tretrop (129) endorses the method for cases of deaf-mutism, especially when careful examination has demonstrated some remaining power for the perception of hearing in the internal ear. As to the dangers or contraindications of lumbar puncture in these conditions, *Babinski* says "presenting no dangers, and not exposing the patient who submits to it (the puncture) to an

aggravation of his trouble, rachicentesis should be tried where there is no special contraindication in all patients suffering from auricular trouble rebellious to the various methods of local treatment." I cannot but think with *Tretrop* that this conclusion is too general, and suggestive of rather more than was meant by the author. Taking him literally, one would naturally proceed to puncture a goodly number of patients, the more so since he does not state after what length of time local treatment should be considered inefficient. In selected cases for the relief of vertigo and tinnitus there certainly appears to be evidence at hand that the procedure is of benefit, and occasionally the deafness has been improved to a considerable extent.

The manner in which these results are brought about must as yet be considered an open question. The changes produced in pressure in the internal ear fluids and the effect these may have on the disease have not yet been sufficiently established to warrant the formation of a theory. A favorable result in deafness should not invariably be expected, certainly not in cases where the labyrinth is destroyed.

Dangers of the Lumbar Puncture: Besides the opinion of many that the lumbar puncture has no very marked value, among whom *Daskiwicz-Korybut* (40), *Stadelman* (41), *Ossipow* (42), and *Braunstein* can be counted, there are quite a few observers who believe the procedure a dangerous procedure. The cases recorded by *Furbringer* (43), *Broca* (44), *Prouf* (45), *Masing* (39), *Mathers* (50), and others are evidence of death caused directly by the puncture. *Milian* (46) holds the procedure responsible for the aggravation of the headaches and nausea. He observed signs of syncope, and interprets these as sequelæ due to disturbances in the balance of osmotic tension and pressure in the cerebrospinal fluid. *Joseph Fraenkel* (51) noted headache and nausea following the performance of lumbar puncture, but he was able to control the symptoms by saline injections.

Other observers, *Heine* (47), *Grossmann* (48), *Lenhartz*, *Quincke*, *Nisel*, and *Kroenig* (49), while not holding the opinion that the operation is dangerous, still do not believe it an indifferent procedure. The concensus of opinion seems to be that the danger is lessened by the avoidance of aspiration of the fluid,

permitting it to come away in a spontaneous flow, and that the operation should be performed while the patient is in a lying posture.

In contradistinction to these views *Chauffard* and *Boidin* (52), in a recent publication, dwell upon the great diagnostic value of the puncture, and consider it a safe means of interference capable of rendering most efficient assistance. *Gordon* (53), *Kohts* (16), and *Conner* (54) coincide with their opinion.

In summing up the question of the dangers from this procedure one must take a conservative position; that it has caused death is undeniable; a horizontal posture lessens the danger, and aspiration of the fluid is to be absolutely condemned. The procedure is contraindicated in cases of vascular sclerosis and aneurisms of the cerebral vessels in all acute and chronic affections of the central nervous system without pressure symptoms arising from the spinal fluid, the more so since the cerebral vessels are secondarily implicated in many of these diseases. The possibility of cerebral hemorrhage should always be kept in mind, especially when withdrawing large amounts of fluid. Small hemorrhages represent no danger to life; they may, however, exercise an unfavorable influence on the patient's future well-being (*Ossipow*).

III. As a Procedure to Produce Anæsthesia: The term "medullary anæsthesia," or "spinal anæsthesia," was first used by *Bier* (140) and *Braun* (141) for the insensibility resulting from an injection of a cocaine solution into the spinal canal; the ultimate cause of this anæsthesia being an interruption of the nervous continuity in the lumbar space, and also of the spinal nerve roots.

Twenty years ago *Corning* (11), the originator of the idea of influencing the spinal marrow (the nerves of the cauda equina) by means of directly applied medicaments, discussed irrigation of the cauda equina with medicinal fluids, referring also to the effects of cocaine on the cauda and its eventual surgical bearing.

The subject in general, and his work in particular, attracted little attention until *Bier* published his article in 1899 on "Medullary Anæsthesia." *Quincke* (2) perfected the technique of lumbar puncture, and *Sicard* demonstrated the analgesia result-

ing as an effect of cocaine injections into the spinal canal of dogs (142). *Chipault* (143), *Jaboulay* (144), *Jacob* (145), and others insisted upon the harmlessness of subdural injections of medicinal agents.

Led by *Tuffier* (146), French surgeons were universally and a little prematurely enthusiastic on the subject of medullary anæsthesia.

The not infrequent direct and remote untoward results caused authorities like *Mikulicz* (147) and others to abandon medullary anæsthesia after having given it a fair trial.

Guinard (148) first recommended the cerebrospinal fluid itself as a solvent for the anæsthetic (cocaine) in order to prevent the meningeal irritation resulting from the physical or chemical effects of the watery solution which had up to this time been used. The same idea had occurred to *Kozlowski* (149), and both these observers soon reported favorably on the results of their improved technique and medication. The otherwise frequent untoward sequelæ of lumbar anæsthesia were absent in all the latter's cases.

It is a noteworthy fact, according to *Braun*, that old, anæmic, and weak patients remained remarkably free from untoward accidents, standing grave and protracted operations without any impairment of their general condition. According to *Morris*, lumbar suprarenin-cocaine injections have never been observed to cause rise in the blood pressure. In some cases the blood pressure remains unchanged, in the majority of instances it falls more or less, most markedly in those cases in which the well-known side effects present themselves and go on to slight collapse, with abundant perspiration, nausea, and vomiting. *Morris* made this observation in nine out of fifty cases.

Without going into detail it suffices to say of medullary anæsthesia that the enthusiastic endorsement accorded it at its introduction into this country some few years ago is on the wane. It is still a valuable procedure in selected cases, but many operators, both here and abroad, have abandoned and condemned it. Deaths occurred directly attributable to the lumbar anæsthesia and to the intoxication from the drugs used.

To modify the phenomena of intoxication, *Bier* recommended

a combination of cocainization with an artificially induced congestive cerebral hyperæmia. The idea is based on the well-known fact that the cerebrospinal fluid is rapidly drawn into the spinal canal when space is encroached upon. A congestive venous hyperæmia will artificially produce such an encroachment. Before the injection of cocaine (or B. eucaine) a bandage is placed so tightly around the neck that it becomes cyanotic, and leaving the bandage in place for some time after operation so as to circumvent the danger of a sudden flow of the cocaine into the brain, together with the cerebrospinal fluid.

The Technique of Lumbar Puncture: The instrument employed to make the puncture is the *Quincke* needle. These needles are procurable in three sizes, of different lengths and diameters. Each needle is fitted with a stilette to aid its introduction. The length of the *Quincke* needle is from four to ten centimeters, with diameters from 0.8 to 1.6 millimeters. The point of the needle is bevelled at an acute angle terminating at a sharp point.

Heiman (157) advocates the use in addition, of a monometer for the accurate estimation of pressure. He uses a monometer tube, fourteen centimeters long with a diameter of 2.5 millimeters.

The position of the patient is important in order to carry out the technique of the procedure easily.

The patient should be placed on his side, with his back gently curved so as to effect as great a separation of the vertebral bones as possible.

Barnhill and *Wales* (158) advocate puncturing between the third and fourth lumbar vertebræ. *Chipault* penetrates into the lumbosacral space, while *Ballance* (159), and others recommend the space between the fourth and fifth vertebræ. We prefer the latter region, as it is easily located because of unvarying guiding landmarks.

The space between the fourth and fifth lumbar vertebræ corresponds to the place where a line when drawn from the highest point on the iliac crests bisects the spinal column. (See Fig. 66.)

The skin of this region is rendered surgically clean. The needle and other instruments are sterilized.

Placing the needle with its contained stilette at the level of the line of the upper margin of the iliac crests where it crosses the spinal column, about ¾ to 1 inch of either side of the spinous process, it is gently and steadily pushed inward and upward at an angle of about 10° from the horizontal.

Occasionally, as the needle is introduced, it impinges against the transverse process, or the inferior articulate process of the vertebra. A slight manipulation of the needle, upward or side-

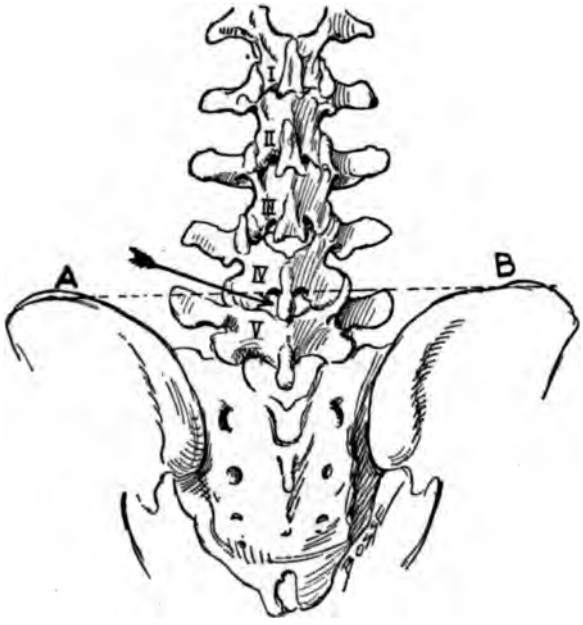

FIG. 66.—LOWER PORTION OF SPINAL COLUMN.

A-B, Line from Highest Parts of Iliac Crests Bisecting Spinal Column. Arrow Shows Puncture Spot.

ways, causes the passage of the needle to the side of the obstruction, to find entrance in the spinal foramen.

The depth to which the needle must penetrate varies in different patients.

This depth averages for children from two to four centimeters, and for adults from four to seven centimeters.

Heiman has devised a safety guard for the needle. This he places in position at the estimated distance from the points

before introducing the needle. Thus he prevents too deep penetration of the needle.

Lumbar puncture is not a painful procedure. General anæsthesia is not necessary. Locally a spray of ethyl chloride suffices to render the puncture of the skin absolutely painless.

The needle introduced, the stilette is withdrawn. A flow of cerebrospinal fluid follows. If the pressure is to be estimated, the monometer is attached, and the height of the fluid read off. The fluid is caught in sterilized test tubes for further examination.

Upon removal of the needle, the site of puncture is covered with a small sterile, and a strap of adhesive plaster.

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CHAPTER XIV

VENTRICULAR PUNCTURE

There are many cases of serous meningitis on record which follow otitic disease. Upon the establishment of drainage such cases are usually cured. They occur mostly in young children, and, because of the severity of their symptoms, a search of the dura is usually undertaken to locate some pus accumulation.

In the majority of these cases, nothing in the nature of an actual meningeal lesion is macroscopically demonstrable. The brain symptoms are usually due to increased tension, produced by the pressure of cerebrospinal fluid in the ventricles or in the subarachnoid spaces.

The treatment of the condition demands the absolute removal of the causative disease in the temporal bone, exposure of the dura, and, if necessary, its incision, and finally, lumbar puncture repeated as indicated. In addition, the lateral ventricle may be tapped through the mastoid wound, or through the small fontanelle.

The exposure of the dura, its incision and lumbar puncture, have been described in their respective chapters. It remains briefly to complete the procedures by a description of ventricular puncture.

In infants, after paracentesis, if symptoms are urgent, the ventricle may be reached through the small fontanelle. The side angles of the fontanelle are chosen as the point at which to introduce the needle. The needle is cautiously introduced in a sideward direction, and in distention of the ventricles—they are rarely missed.

In cases of serous meningitis, due to otitis, however, the primary foci of disease in the temporal bone having necessitated operation, it seems wiser and also more advantageous to enter the ventricle from the mastoid wound cavity.

The tegmen is exposed and opened. The dura is laid free, and the needle introduced directly through this membrane, inward and upward, to a distance of about 4 to 6 cm. In many cases, it is found advantageous first, to incise the dura, and then to puncture through the brain substance. The latter procedure has the added advantage that it drains the subdural space.

Ventricular puncture has been advocated by *Bonninghaus* (1), *Jansen* (2), *R. Müller* (3), *Hammerschlag* (4), and others, and has a distinct place in otological surgery. See Fig. 60 for landmarks.

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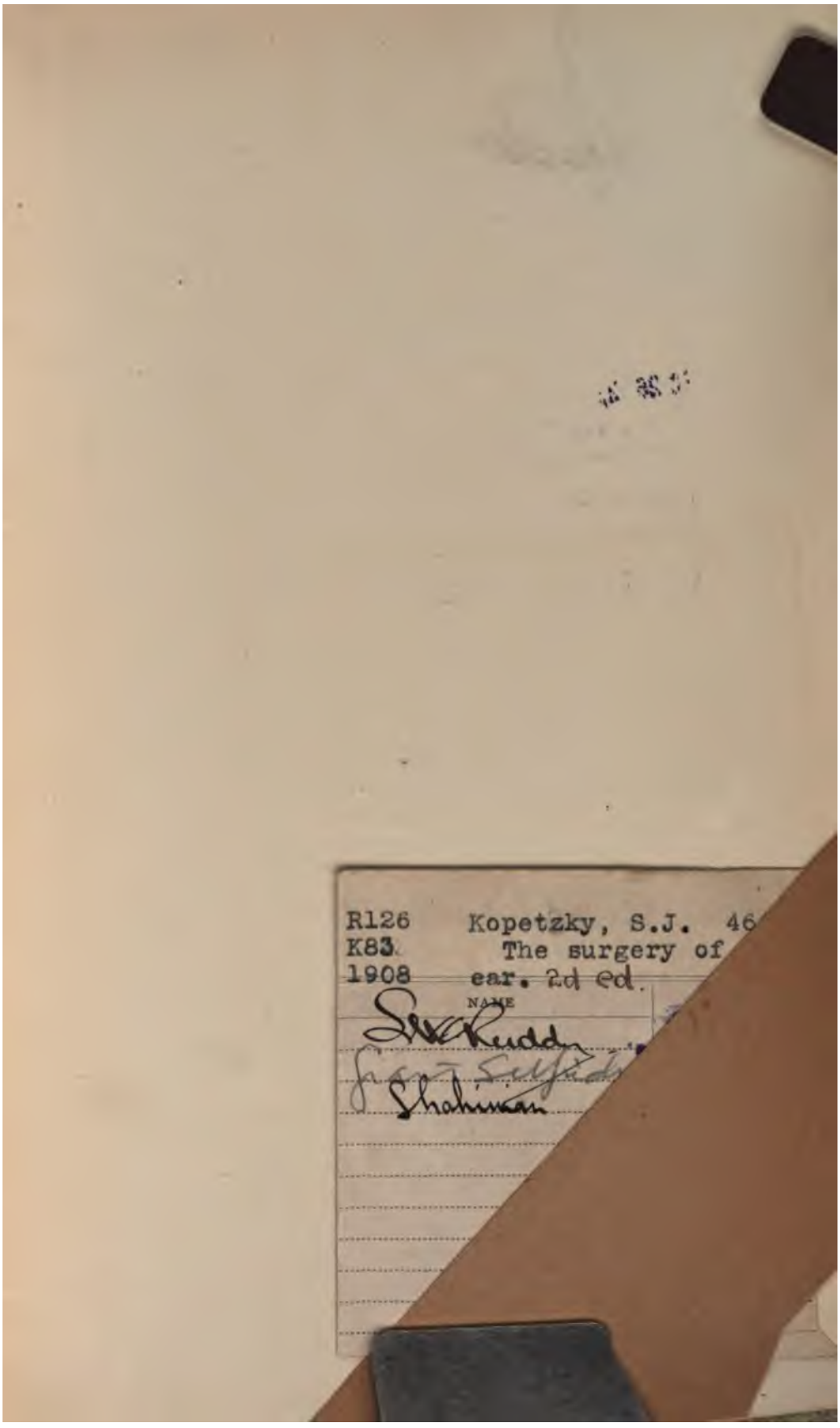
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